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FIRST LESSONS
IN
GEOLOGY

BY
A. S. PACKARD JR.
PROFESSOR OF ZOOLOGY AND GEOLOGY. BROWN UNIVERSITY.

TO ACCOMPANY THE CHAUTAUQUA SCIENTIFIC DIAGRAMS
SERIES NO. I - GEOLOGY

PROVIDENCE R.I.
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1882

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LESSONS IN GEOLOGY,

—BY—

A. S. PACKARD, Jr.

Professor of Zoology and Geology, Brown University. Author of
"Guide to Study of Insects," "Zoology," etc.

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CHAPTER I.

(*Diagram I.*)

THE ACTION OF WATER.

If we walk out of the town or village in which we live, and observe carefully the cuttings by the roadside, or the bank of some stream or railroad cut, we shall see overlying the sand or gravel a layer of soil or loam. Upon closely examining this soil we shall find that it is not of the same nature throughout, but that next to the surface it is composed of dead and decaying leaves and stems of plants mixed with the roots of the trees and shrubs growing in the soil. Deeper down, the soil will be found to be less dark and more sandy. Finally we come to the sand or gravel. Let us now examine the gravel; and the coarser it is, the better for our purpose. Taking up a handful let us turn over the miniature pebbles. There are little masses of milk-white quartz, which are more or less angular, because quartz is the hardest mineral among those to be found; we also find little pieces of rounded feldspar, a flesh-colored or whitish mineral which is softer than the quartz because we can break it easier, and it is easily scratched by the quartz; we also find minute scales of mica which glisten in the sun. These three minerals form granite. We also find pebbles of a fine-grained granite, and mingled with them pebbles of granite with the minerals composing it arranged in layers; this is called *gneiss;* besides these we may find little pieces of a greenish-black, very hard rock called greenstone or trap. If the cut has been freshly made we shall see that the gravel or sand is arranged in regular layers called *strata,* and that the sand bank is layered, or *stratified.* This division into layers or *strata* is called *stratification.*

Action of Rivers.—Now what has caused this stratification? Let the stream below answer our question. If the stream bends in its course and is not too sluggish, we shall see that the material forming the bottom is not uniformly distributed. Where the stream is swift, the material is coarse and gravelly, while the material in the bend opposite the gravelly point is of fine sand; then at the bottom of the eddies the material is very fine or muddy.

Now if there has been a recent shower, and the stream is rather high and the water thick and turbid, should we take up a tumbler-full of the water and allow it to settle, we shall see that the coarser particles fall to the bottom first and form a layer or *stratum* of gravel; above it is next deposited a layer of sand, and finally when the water has become clear, all the sediment having fallen to the bottom, we shall find uppermost a stratum of very fine sand, so fine that we cannot easily distinguish the particles, and this is mud. The entire deposit is said to be, in geological language, *a sedimentary deposit.*

Now how did the mud become mud, the sand become sand, and the gravel become such? What did the work? Let the hurrying, rippling, busy stream at our feet again answer. It was running water. It is running water which in the spring time overflowing the banks of the stream, wears away and undermines them, carrying along a heterogeneous mass of stones and sand, which are rubbed together and worn down until the larger angular stones become small rounded pebbles, the latter coarse gravel, and finally the gravel becomes worn away, the particles forming sand and mud. The stream is, perhaps, but one of many branches or tributaries of some great river, and all the members of this great river-system, year in and year out, century after century; and not only this, but all the tens of thousands of river-systems over the surface of the earth are, and have been for ages, engaged in this work of the transportation of sediments from the highlands to the lowlands, the finer part of which, called *silt*, reaches the ocean.

It has been estimated that the amount of silt carried to the Gulf of Mexico by the Mississippi is equivalent in an average year to 812,500,000,000 pounds, which would form a mass one square mile in area and 241 feet deep.

Dana also states that besides the material held in suspension, the Mississippi pushes along into the Gulf large quantities of earthy matter, and it is estimated that "the annual amount thus contributed to the Gulf is about 750,000,000 cubic feet,—which would cover a square mile 27 feet deep, and this added to the 241 feet above, makes the total 268 feet."

Now the whole area of the United States drained by the Mississippi is very large, as a glance at a map will show our readers. This vast area is supposed by the action of the Mississippi to be lowered, on an average, one foot in 4,920 years. The Ganges, adds Dana, "works faster, the amount it transports to the sea being such as would lower its drainage area, on an average, a foot in 1,880 years." The annual discharge of sediment from the Ganges has been estimated at 6,369,000,000 cubic feet, or 756,200,000,000 pounds. The Nile brings down annually nearly 300,000,000,000 pounds of silt.

Erosion.—But the transportation of all this silt or fine sediment is by no means all the work done by rivers. If we ascend our stream to where it passes out from the highlands or mountains, we shall find that the banks of gravel and sand or loam, are there replaced by rock; that the stream before it reaches the fertile plains of the lowlands, has passed as a roaring foaming torrent through a mountain gorge, or cañon, as it is called in the Far West.

Careful observation will convince us that the stream has cut down and deepened its channel, and in so doing has *eroded*, or eaten away its banks. This process is called *erosion.* This work of erosion is aided by the great stones and gravel and soil which fall down the mountain or hillsides into the streams; and the loose material carried along with great force by the torrent rasps and scrapes away or *erodes* the rocky sides of the streams.

Now if the sides and bed of the stream are of hard granite or gneiss, the work of deepening the bed will be slow, and the channel often broad and irregular; but if the rock is a soft friable sandstone or limestone the channel will be deep and the sides straight and precipitous as the channel of the Niagara, or the cañon of the Colorado.

That the stream does this work of erosion often with rapidity is suggested by the rate at which hills are leveled and rock-channels are worn away by the process of hydraulic mining. Those who have crossed the continent and looked down from the Central Pacific railroad-train after it has descended from the summit of the Sierra and reached the foothills, will remember the scenes of desolation, the forlorn wrecks of forest-covered hills and green slopes, which meet the traveller's eye near Dutchman's Flat and other localities. The force and erosive power of the stream issuing from hydraulic pipes is astonishing. At one hydraulic mine on the South Yuba river a pebble-loaded torrent working eight months a year has in four years cut a channel in solid slate rock three feet wide and fifty feet deep.

From where does all this loose material which falls into the river come, and how is it carried down and cast into the stream? The question in part is easily answered as regards the mountain region. When we ascend the wagon road of Mount Washington or the ravines and valleys descending from any mountain summit, we see that the rock has crumbled and broken up, or been disintegrated by the action of frost.

In the winter time the snows and frosts perform this important work of separating great masses of rock from the parent rock. The snow or rain enters the cracks, and, freezing, causes pieces of rock to break off; in the same way the larger blocks of granite, gneiss, slate, or limestone, as the case may be, are broken into smaller fragments; meanwhile the oxygen in the air acts upon the smaller pieces; and the feldspar in granite and gneiss rocks easily crumbles, until a heterogeneous, ill-assorted mass of angular or partly-rounded stones, mixed with soil and gravel, forming what is called *débris*, lies on the mountain summit, ready to be carried down as slides or avalanches when in the spring the snows melt and storms of rain succeed the snow storms. All through summer and autumn this work of breaking up and lowering the mountain summits, and feeding the ravenous mountain torrents goes on.

In the lowlands, moreover, the disintegration of rock surface goes on with rapidity and thoroughnes. During the war of the rebellion we have marched for miles and miles along railroads through deep cuts in southeastern Virginia, through masses of loose gravelly disintegrated rock, perhaps thirty to fifty feet or more in thickness. Veins of quartz rock stood here and there out from the mass, the latter by the bands of different color, which were once different strata, showing that it has resulted from the wholesale disintegration or crumbling of the rock in place. This effort of the combined action of the sun's heat, of frost, rain and the carbonic acid in the air carried into the substance of the crumbling mass by rain is seen all over the warmer parts of the earth. It has been noted in North Carolina, in Georgia, and especially in Brazil. The rich soil of the western plains, above and beyond the river bottoms or prairie lands, is due to the decomposition of the underlying rocks, consisting of limestone, earthy sand rock, hardened marls, which in past ages formed the muddy and sandy bottoms of the vast lakes of Tertiary times.

All this loose crumbling material is washed down by rivers which form miniature gorges and cañons and gulches in the sides of clay or sand banks, or hills and slopes, which may appear in a few hours as the result of a sudden thunder-storm. The miniature torrents combine to form the little rills, which pour their treasures of silt into the brooks, and thus over the entire storm-area the crumbling material is carried into the brooks, reassorted into mud, sand and gravel, and finally reduced to silt, which is spread out over the lowlands, in part forming the prairie bottoms, interval lands and swamps, and in part reaching the sea.

Such is the work done in all parts of the earth by rain and running water; and this work is called *atmospheric erosion.*

Glaciers.—In portions of the northern and southern hemispheres, and at great heights in elevated mountain ranges such as the Alps, the Himalayas and the Polar regions, this work is locally aided by the action of land ice or *glaciers.*

Glaciers (see Diagram X) are rivers of ice filling Alpine valleys, and descending at a very slow rate of motion below the limits of perennial snow. They arise from a snow-field or *mer-de-glace* on top of a mountain range, which overflows, sending streams down the valleys radiating from the central snow fields. They are naturally largest where the mountains are highest and the rainfall greatest. The conditions for the formation of glaciers are (1) great elevation above the snow line, (2) a low temperature with considerable changes and therefore alternate thawing and freezing, and (3) a considerable rainfall. These conditions are fulfilled in the Alps, and the lack of such conditions in the Rocky Mountains and the Sierra Nevada, makes their presence there very rare.

The largest glacier on the Pacific Slope of the United States is the Whitney glacier of Mount Shasta. It is three miles long, while those of Europe and the Himalaya mountains are from five to twenty miles in length.

In the polar regions, especially Greenland, they are of great extent. Indeed the interior of Greenland is covered with an almost unbroken sea of ice, from which ice-streams move down into the sea at an annual rate of about sixty feet a day. As the glacier moves down into the sea it pushes before it a great mass of stones, gravel and mud, which forms a submarine bank, while the ice breaks off in great blocks or icebergs, which float away and are carried out of Baffin's Bay down past the coast of

Labrador as far as the Banks of Newfoundland, where they melt away.

During two voyages to the coast of Labrador, the second one to Hopedale, the southernmost Moravian station, we have had excellent opportunities of watching the majestic march of these monarchs of the polar regions, as borne on by the Labrador current, enclosed in the ice-pack and buffeted by the winds and waves of that stormy coast, they moved on in their resistless course, objects of mingled awe and dread. At sunrise and again lighted up by the rays of the setting sun, their marble sides would glow with the richest, warmest tints. What a story had these mountains of ice to tell! Born of the rain and mist in the centre of the Greenland plateau, their massive forms built up of the purest ice were most solid and compact compared with the innumerable hosts of spongy, melting berglets of floe ice, which followed them as an army its leader. What a work had they done towards smoothing and polishing the rocky floor of the land they had left, and now their life's work over they were marching to their death and dissolution in the warmer waters of the mid-Atlantic.

The story of a glacier is an interesting one. All that has been written about glaciers would fill a library. The keenest intellects, both naturalists and physicists, have united their efforts in unravelling the laws of their motions, which are now considered to be similar to those of a river. For example, (1) the central portion moves faster than the edges; (2) the velocity of the surface is greater than that of the bottom; (3) the velocity increases with the slope; (4) the velocity increases with the fluidity; (5) the velocity increases with the depth; (6) fluid currents conform to irregularities of their channel, and (7) the line of swiftest motion is more sinuous than the channel. These are the laws of river-motion, but they also apply to that of a glacier, which may be called a river of ice.

That glaciers moved was known to the Swiss mountaineers, and proved experimentally by Agassiz. A Swiss observer, named Hugi, in 1827 built a hut on the surface of the Glacier of the Aar. In 1841 Agassiz found that the hut had moved 1428 metres, or about 100 metres (330 feet) a year. By driving a line of stakes into the ice from one side to the other of the glacier, it was found by Agassiz and Forbes that the centre moved faster than the margin, hence the theory of differential motion, which asserts that the different parts of a glacier do not move as a solid, but move among themselves like a stiff, viscid fluid, such as molasses or pitch.

It has also been found that the daily motion is greater in summer than in winter, and in midday than at midnight. The glaciers of the Alps, with a thickness of from two hundred to three hundred feet, have a mean daily motion of from one to three feet, while in Greenland, a glacier, perhaps, from two to three thousand feet in thickness, and in spite of the much lower temperature of that region, is known to move sixty feet in one day.

Glaciers also grow and recede, advancing some years after a heavy rainfall so as to invade the farms and hamlets of the Swiss peasants; and then melting away in front and, as it were, retiring for several hundred feet. Within the last twenty-five years the glaciers of Switzerland have (according to Favre) generally receded. According to Dufour, the glacier of the Rhone receded 260 feet in the course of two years.

In 1877 the writer ascended Mount Shasta, and from information given by the guide, who had ascended the mountain four years previous, it was found that the surface of the Whitney glacier was about a hundred feet lower than in 1873.

Over the usually clean, brilliant surface of the glacier are here and there scattered stones or patches of dirt; these absorb the sun's heat, the ice melting under them. Wherever the glacier pitches down over the inequalities of its rocky bed the ice rends asunder with a loud report, and thus a *crevasse* is formed. These fissures usually extend near or quite to the bottom. The surface streams tumble into these crevasses, wearing deep holes extending to the bottom. The numerous streams carry down with them stones and gravel, and form under the glacier a stream which finally excavates a cavernous outlet at the end of the glacier, whence the water, turbid with the glacial mud, the scourings of the rock under the ice in which are frozen pebbles, gravel and large stones, issues as a wide brook. Thus the sources of the Arveiron and of the Rhone rivers issue as milk-white glacial streams from ice-caves.

These sub-glacial torrents, bearing their burdens of stones, sand, and glacial mud, are, according to Professor Niles, a most efficient agent in smoothing and wearing down the rocky bed of the glacier.

Most important features of glaciers are the long, steep hills of *debris* along their edges, next to the sides of the valleys, and the great mound of loose material pushed in front of the glacier in its advance. These mounds of dirt and gravel are called *moraines.* Those which are situated on the sides of the glacier are called *lateral moraines;* they are formed by the dirt, gravel and loose rocks which fall either singly or in slides or avalanches from the sides of the mountains rising above the glacier. Where two glaciers unite at the union of two valleys, two of the lateral moraines unite to form a *median moraine.* The semicircular mass of *debris* pushed by the front or end of the glacier is the *terminal moraine;* while the material beneath, supposed at times to be abundant, is called the *ground moraine.* A section of a moraine of any kind shows that the material is not assorted, but looks as if stones of all sizes and shapes had, mixed with soil, gravel, sand and clay, tumbled pell-mell upon each other.

The larger stones in or upon the top of a moraine are called *boulders;* and those under the glacier or in the ground or terminal moraine are usually rounded, smoothed and polished, and often scratched. This has been effected by their wearing down in the sub-glacial stream, or from having been frozen in the ice and held like chisels or gouges in the vise-like grip of the glacier.

The effect of the moving mass of ice, with its immense weight, is most interesting. The rocky bed of the glacier, as well as the sides of the valley, are worn down, often for many feet, and variously scored, fluted, grooved, scratched and polished by the bottom ice in which the sand, gravel and boulders are frozen. These marks are called glacial grooves, or glacial scratches or ice-marks. Sometimes transverse, crescent-shaped furrows are made in a rock by boulders which have been frozen into the ice, and by the slight advancing and receding motions of the immensely heavy mass of ice wear out a crescent-shaped depression, the concave side pointing towards the glacier, or the valley which once held the glacier. Such *lunoid furrows* we have observed in the White Mountains and on glacial polished surfaces on the coast of Labrador.

Hence it will be seen that the amount of erosion performed by glaciers is immense. Moreover, masses of rocks forming the highest pinnacles of the Alps have been transported for many miles down the mountain valleys. One such travelled rock in the lower Alps measured 250,000 cubic feet.

Agassiz discovered polished, grooved rocks, moraines and travelled boulders all over Switzerland, in Scotland and Wales, and hence he conceived the theory that nearly the whole of Europe, not only the Alps of Switzerland, but France, England and northern Europe, had been covered by land ice. When in 1847 he landed at Halifax, Nova Scotia, and afterwards travelled through New England, and visited the White Mountains and Lake Superior, he claimed that not only Europe but North America had been covered with an ice-sheet. This is the *glacial theory*, and the period during which the northern hemisphere was thus clad in ice is called the *Glacial Period.* In eastern North America the most southern point where glaciers now occur is on *Meta Incognita* in Frobisher's Bay in latitude 62° N., on the northern side of Hudson's straits. The Grinnell glacier was discovered by Capt. Hall, who died while in command of the "Polaris." This glacier is one hundred miles long, resting on a table-land from 1000 to 2000 feet above the sea. From this table-land glaciers descend into the sea, and icebergs break off from them and float away down the Labrador coast.

That the Labrador peninsula was not long since covered with land ice which filled the countless fiords or long narrow bays of that coast, the writer has found good proof, in perched, travelled boulders, smooth and polished rock surfaces marked with the peculiar crescent-shaped furrows already described. In latitude 55°, in August he observed banks of snow extending into the sea like miniature glaciers. This shows that only a slight elevation of the land and lowering of the temperature in summer would be needed, as the rainfall is already very heavy, to bring back the glacial period in Labrador.

In Canada, New England, and the Northern States, the rocks are everywhere polished and grooved, the course of the scratches usually following that of the larger river valleys. Moreover, in northern New England there are trains of boulders, marking the former direction of the glaciers which bore them away from their parent rock, some hill-top or mountain height. Moreover, in the White Mountains, besides polished rocks and moraines precisely like those to be seen at the edge of glaciers in the Alps, we have observed glacial grooves pointing down the different valleys radiating from Mount Washington, and showing that the valleys of the Peabody, Androscoggin and Saco rivers were formerly filled with glaciers, the ice capping the whole White Mountain range, the glaciers descending thence into the sea at Portland, Maine, and by the Merrimac Valley into the sea near Newburyport.

In fact, a nearly continuous ice-sheet, thin on the hills and mountain ranges and thick in the valleys, and divided into more or less separate glaciers occupying different river valleys, covered the northern United States, and by several of our geologists it has been ascertained that the southern edge of this ice-sheet probably extended southward to a line extending from Cape Cod and Nantucket westward through Long Island across to New Jersey, to Belvidere, through northern Pennsylvania, thence bending south through southern Ohio, Indiana, and Illinois. This line is indicated by a series of singular hills, gravelly ridges and deep holes or hollows called "kettles," supposed to be the end of a great terminal ground-moraine. In New Jersey the line extends west of Perth Amboy, and it is thought that while the ice-front along the coast of Maine and Massachusetts north of Cape Cod may have been about a thousand feet thick, that in New Jersey the end of the great glacier formed an ice-front three hundred feet high.

The ice also covered the State of New York, the northwestern corner of Pennsylvania, and Ohio as far south as the 38th parallel of latitude; thence it took a general northwesterly direction towards Lake Superior, passing by St. Paul, Minnesota, and following a general northwest direction along the western borders of Lake Winnepeg. This ice-sheet was probably not an unbroken sheet, with no hills or mountains projecting above it; for the summit of Mount Washington is not rounded and ice-worn, as are the lower peaks of Jefferson, Madison and Lafayette, and the extreme summit of Mount Ktaadn in Maine probably projected above the ice-sheet, while near its southern limits in New Jersey it did not cover the higher crests of land.

On the Pacific Slope this ice-sheet enveloped the Cascade Range and extended as far south as the Columbia river. While journeying from Portland, Oregon, to the head of Puget sound, and especially at Victoria, Vancouver Island, we were able to observe all the geological phenomena so familiar to us in New England, viz., moraines, grooved and polished rocks, and marine clays abounding in shells.

South of the limits we have laid down, no glaciers are known to exist along the entire Rocky Mountain range, except one on the Wind River Mountains in northern Wyoming Territory. A few glaciers have been discovered by Clarence King on the summits of the Sierra Nevada in California, and Mount Hood in Oregon has existing glaciers capping its summit, while three glaciers, of which the largest is the Whitney glacier, extend down the sides of that magnificent extinct volcano, Mount Shasta.

We have had the privilege of ascending the crater of this, the finest mountain peak on the North American continent, which rises over 12,000 feet above the plain, which is about 2,000 feet above the level of the sea. We have traced the successive curved ridges of boulders of lava, trachyte and andesite which extend down to the plain, some twelve or fifteen miles from the summit of the volcanic cone, until the miniature moraines, formed of rounded stones which a child could roll and toss about, lay in concentric circles on the plain over which the stage road passes. It is evident that in former times the Rocky Mountains above an altitude of 7,000 and 8,000 feet were capped with ice, with glaciers descending down to the foothills; and so with the Sierra Nevada; but there is no good evidence that the plains west of the Mississippi River, those of the Great Basin or of southern Oregon and California were ever invaded by ice.

It is evident, then, that in northern Europe and America the erosive power of the rivers has been greatly aided by the action of glaciers. Moreover, during the height of the Glacial period, to which we shall return in our last lecture, the land stood higher than now, and as the ice melted, the rivers were much broader, though shallower, than at present, and thus the erosive power of these great post-glacial rivers, of which the Penobscot, Kennebec, Merrimac, Connecticut, Hudson and Ohio rivers are but the dwarfed and attenuated descendants, was enormous and widespread compared with the present time.

We are now prepared to appreciate what a pervasive and powerful influence running water has exercised in carving and sculpturing the earth's surface. It has aided the great mountain-raising forces of which we speak in the next chapter, in carving out peaks and pinnacles, in gouging out cañons and ravines, as well as broader valleys; it has spread out broad prairies, fertile plains, and rich intervales, thus preparing the earth for the residence of man; and has produced the most picturesque and striking scenic features, to develop his æsthetic tastes and his imaginative and creative powers.

Let us now look at some of the effects of running water, and first at the Falls of Niagara (See Diagram I.) At present the falls are 167 feet high, and owing to the wearing away of the rock over which the river pitches, they are supposed to recede at the rate of from one to three feet each year. But the fall has not always been at its present site. It was originally situated at Queenstown, and the river has thus worn its channel back six miles. The gorge itself is, for the most part from 200 to 250 feet deep, and at the fall is 160 feet deep. The diagram shows that a bed of grayish limestone 80 feet thick overlies a bed of soft pinkish shale, also 80 feet thick; the softer friable shale is worn away by the river, so that the harder limestone above is undermined and occasionally falls down in great blocks. It has been estimated that the time required to make this gorge is not under 30,000 years.

The lower figure on the right of the diagram illustrates the formation of a new set of river beds, in California, which the rivers have cut in very recent times, through (*a*) columnar basalt and volcanic ashes, and through (*b*) old river gravel, into (*c*) tertiary, and (*d*) Cretaceous strata.

One of the most wonderful gorges in the world is that worn by the Columbia river through the Cascade range at the falls of the Dalles. As one sails up the majestic river and approaches the Cascades, the banks of the Columbia, which rise in sheer precipices from 2000 to 3000 feet above the river's brink, recede, until a waterfall on the northen bank, said to be 800 feet high, losing itself in spray before reaching the river, when seen from the steamer's deck appears as if but a white ribbon flung against the wall. The river has cut this great gorge through the hardest sort of volcanic rock, but here as at Niagara Falls, the harder rock is underlaid by a softer kind, which wears away and thus undermines the hard basalt overlying the softer amygdaloid rock beneath.

In like manner the famous American Fork Cañon, a narrow gorge in the Wasatch Mountains in Utah, with sheer precipitous walls over 2000 feet high, whose tops are fretted and worn into rugged sharp pinnacles, has been worn by a mountain torrent through the Carboniferous limestone.

But the most remarkable example of gorge-cutting is the wonderful Cañon of the Colorado, first described by Prof. Newberry and more fully by Maj. J. W. Powell, who made the passage of the river through this gorge, and from whose work the view on the right in Diagram I. is taken.

The picture is a bird's-eye view, and represents three great terraces through which the Green river, or upper Colorado, has cut a deep cañon. "The escarpment below, in the foreground, represents the Orange Cliff, at the foot of Labyrinth Cañon; the second escarpment, the Book Cliffs, at the foot of Gray Cañon; the third, away in the distance, the Brown Cliffs, at the foot of the Cañon of Desolation. It will be seen that the three tables incline to the north, and are abruptly terminated by cliffs on the south. For want of space the whole view is shortened. In the three cañons there are three distinct series of beds, belonging to three distinct geological periods. In the Cañon of Desolation we have tertiary sandstones; in Gray Cañon, Cretaceous sandstones, shales, and impure limestones; between the head of Labyrinth Cañon and the foot of Gray Cañon, rocks of Cretaceous and Jurassic age are found, but they are soft, and have not withstood the action of the water so as to form a cañon. . . . . The climate is exceedingly arid, and the scant vegetation furnishes no protecting covering against the beating storms. But though little rain falls, that which does is employed in erosion to an extent difficult to appreciate by one who has only studied the action of water in degrading the land in a region where grasses, shrubs, and trees bear the brunt of the storm. A little shower falls, and the water gathers rapidly into streams, and plunges headlong down the steep slopes, bearing with it loads of sand, and for a few minutes, or a few hours, the district is traversed by brooks and creeks and rivers of mud."

The Grand Cañon of the Colorado is about 4000 feet deep. It is not a simple gorge, but presents a vast system of cañons with "granite buttresses set with pinnacles and towers, then broken slopes, then sombre recesses, set with ragged shelves, then strangely carved and fretted slopes and lemon-colored shales, then vast amphitheatres of marble, then red slopes and sandstone shelves, then cliffs of ragged limestone, set with towers." (Powell.)

Of this region Lieutenant Ives, who explored the lower Colorado, and saw the Grand Cañon region from a distance, thus writes in his report: "The extent and magnitude of the system of cañons in that direction is astounding. The plateau is cut into shreds by these gigantic chasms, and resembles a vast ruin. Belts of country, miles in width, have been swept away, leaving only isolated mountains standing in the gap—fissures, so profound that the eye cannot penetrate their depths, are separated by walls whose thickness one can almost span, and slender spires, that seem tottering upon their base, shoot up a thousand feet from vaults below."

Another striking feature of the west are the "Bad Lands." These show the erosive effects of running water on a vast scale. A familiar example are the peculiar scenic features of the vicinity of Green River Station on the Union Pacific Railroad. The view on the left in the Bad Lands of the Green River is taken from Powell's Report on the Colorado River. The party of explorers have emerged in their three boats from Labyrinth Cañon and have come into the "Land of the Standing Rock." The undulating surface of the region is naked, solid, beautiful red sandstone; and a prominent landmark is the "Buttes of the Cross," two lofty mountains, like pinnacles, left by erosion.

As striking as any scene in these "Bad Lands" are the precipices shutting in the Upper Missouri, about half a day's sail down the river by steamer from Fort Benton. As we approached the gorge which shuts in the Missouri at the Dauphin rapids, the shades of night were mantling with gloom the lofty pinnacled cliffs which rose nearly two thousand feet above the river; and to add to the interest of the scene, a squad of mountain goats which seemed no larger than rabbits filed along a narrow path on the dizzy heights above.

The Western Territories teem with such wonderful evidences of the erosive power of water. The cañon of the Madison and the Prickly Pear Cañon in Montana, through which we have ridden for eighteen miles, the banks of the upper Columbia, the rapids of the Snake River, the Valley of the Yosemite in California, have left ineffaceable impressions on our mind of the all pervading and silent power of so simple a geological force as running water. The deep cañon-like valleys of Norway are valleys of erosion. How running water has here done its work may be seen by the following extract from a Norwegian sketch which we contributed several years since to a magazine:

"We are now nearing the Fille Fjeld, or height of land, where the snow remains in banks throughout the summer, and from the region about Skogstad, situated at the foot of the Fille Fjeld, we can study the effects of the denuding forces which have produced these unique scenic features.

The torrent, rushing by, bearing on its bosom the foam of the waterfall, tells the story. For ages and ages the cataract has been retreating up the valley, deepening its channel and spending its force until reduced to the small stream we now see. Forty or fifty feet above the present level of the river are a number of pot-holes, like wells dug out of the mica slate flooring of the valley. These reveal the secret of these deep, dark Norwegian gorges. Like the cañons of the Colorado, or the

Valley of the Yosemite, they have been worn out by the slow, ceaseless action of running water. The work of glaciers was an efficient aid, but not the sole cause. They have simply remodeled the valleys. The granite cones have resisted these eroding agents, and the broad summits of the long mountain-swells have afforded a lodging-place for the reservoirs of ice, the *mers de glace,* from which glaciers have flowed into the valleys."

It is so simple an agent as running water rather than volcanic upheavals, which has, late in the world's history, changed the face of nature, and adorned the earth with carved work, combining grandeur and sublimity with a delicacy and beauty of finish which elevates and informs the soul of man with the loftiest and finest feeling.

Everyone is impressed with grand or beautiful scenery, but what an added relish to the soul's appetite is lent by a knowledge of the geological causes and methods by which the Creator has prepared the world for the abode of that being who alone of the myriad forms of life can enjoy the beauties and wonders of creation, and unravel the secrets of nature. The enjoyment of the every-day scenes about us, the pleasure of any country ramble, are immeasurably heightened by a little geological knowledge, and one needs only to be an industrious traveller and shrewd observer in his own township to become enough of a geologist to enjoy and appreciate scenes which to the uninstructed eye possess little or no interest.

Action of the Ocean.—We have now obtained some idea of the action of rivers. Let us next learn what work the ocean does in wearing down or building up the land. All the sediments carried by rivers into the ocean are taken up by the waves and tides, and re-distributed. In this way the coast of North and South Carolina and Georgia has been built up and extended. The *debris* of continents, however, are not to be found far from shore. Below a depth of from 500 to about 2000 feet, but little if any land *debris* is to be found, the abysses of the ocean being strewn with the shells of minute protozoans, which are different kinds of animalcule, forming a soft ooze.

The ocean does its work of erosion by waves and tidal currents. Waves tear down the headlands and capes, and the tides assisting them, further the work by spreading the sand along the shores of bays, filling them up; the finer mud dropping into the quiet depths of harbors and deep bottoms of bays beyond the reach of waves and tides.

The action of waves is confined to the coast line, and is most powerful between high and low water mark. Some one has estimated the average force of waves on the coast of Scotland in the summer season at 611 pounds per square foot, and for the stormy winter months at 2,086 pounds per square foot; while during violent storms the force may amount to 6,000 pounds the square foot, and rocks of many hundred tons' weight are often hurled inland. Similar action may be observed along the coast of northern New England, and on our great lakes.

Waves wear out caves, pot-holes and deep fissures called "purgatories," and such features, with sea-worn cliffs, found inland, mark the former ocean-level. Lines of such cliffs and even limestone caverns, mark the former level of the Great Salt Lake. We have found in one cavern about 200 feet above the present level of the Great Salt Lake numerous shells, which formerly inhabited the waters of the lake when they were fresh and sustained abundant life.

The erosive work done by tidal currents is especially powerful on the coast of Maine and in the Bay of Fundy, which is swept by powerful currents, which tear down the headlands of soft red rock and strew it along the ocean's bottom for miles away, and also carry it to the head of the bay, strewing it over the Basin of Minas. Outstanding pillars and high islets called "drongs" are thus separated from capes, as seen at Jewell's Island in Casco Bay, the old Friar at Eastport, and at points in the Bay of Fundy. Along the coast of Norway, in the region of the maelstrom, which is nothing but the effects of conflicting tidal currents, the famous Lofoden islands are evidences of the powerful wearing action of tidal currents. Tidal currents are especially strong among islands and narrow channels. The ebb or outflowing current is the deeper, and therefore exerts more excavating and transporting force than the incoming tide, as the former begins to flow out before the tide is wholly in.

By the combined action of waves and the efficient aid of tidal currents, Cape Cod is constantly changing its form. Cape May in New Jersey is said to be wearing away at the rate of about nine feet a year. In England the cliffs of Norfolk have been removed at the rate of three feet a year, and those of Yorkshire are disappearing at the rate of six feet a year. Churches and parts of villages have thus been destroyed, and in the German ocean islands have been washed away within historic times. In this way the land is torn down and carried out to sea to form bars, spits and submarine banks.

The land, by the different means we have attempted to describe, has been worn down, and carried into the sea, forming beds of sand and mud at the bottom of the ocean. The shells of countless animals, coral masses built up by the coral polyp, mingle with the clay and sand, forming beds of what under pressure become limestone. And thus the beds of limestone, shale, sandstone and marl, constituting a large proportion of the earth's surface have been formed. When such beds or strata contain the relics, or shells, or bones of extinct animals, called *fossils,* such rocks are said to be *fossiliferous.*

Now when we compare the fossil remains in rocks, with the shells and corals of existing times, or the bones of extinct animals with those of existing mammals, or reptiles, or fishes, we find, what astonished Cuvier in the opening years of this century, that almost without exception the fossil animals were unlike those now living. And by a study of the bones and skeletons of existing quadrupeds Cuvier was able to make such comparisons with the fragments of fossil bones and teeth, that he could more or less correctly restore their forms while in life.

The science of the study of ancient life is called *palæontology;* and those who devote their lives to the study of fossils are called *palæontologists.*

It has been found that each formation of rocks contain distinct sets or assemblages of fossils, unlike, as a whole, to those found in strata either above or below. Hence fossils are time-marks, serving to identify the age of different beds. Thus the age of the gold-bearing rocks of California was settled by the fortunate discovery of an ammonite which showed that they were Jurassic. The finding of a *Productus,* a sort of shelled worm, (Brachiopod) in limestone rock, proves that such rocks are most likely to be of Carboniferous age.

So geologists speak of the Devonian formation as rocks of the age of fishes, and the Mesozoic (Trias, Jura and Cretaceous) as rocks of the age of reptiles. Any assemblage of animals peopling a spot on the earth's surface is called a *fauna;* and the plants of a region constitute its *flora.* Thus geologists speak of the Carboniferous flora, or of the Tertiary fauna.

Thus with the aid of fossils the earth's age or geological time is divided into eras, as follows; and the eras subdivided into periods, epochs and ages.

ARCHÆAN ERA,	Laurentian Period.	
	Huronian Period.	
PALÆOZOIC ERA,	Silurian Period (Age of invertebrate animals).	
	Devonian Period (Age of fishes).	
	Carboniferous Period (Age of coal-plants).	
MESOZOIC ERA,	Triassic Period.	(Age of reptiles).
	Jurassic Period	
	Cretaceous Period.	
CENOZOIC ERA,	Tertiary. (Age of mammals.)	
	Quaternary. (Age of man.)	

The estimated thickness of the Archæan stratified rocks is from 40,000 to 50,000 feet; that of the Palæozoic beds is estimated at about 40,000 feet; while the Mesozoic rocks are supposed to be from 20,000 to 30,000 feet in thickness, and the Tertiary and Quarternary rocks together are not less than 10,000 feet. These amounts are the sum of the thickest deposits of the several formations, and not the thickness observed in any particular place (Dana).

The time required by geologists for the deposition of these strata, and the building up of the great continental masses of the earth, is to be reckoned by millions of years. Astronomers and physicists, however, now maintain that the age of the sun is about 20,000,000 of years, and this limit is adopted by geologists, for they have no arbitrary limits by which to mark off geological time. The average opinion of geologists has, perhaps, been expressed by Mr. A. R. Wallace, who, after remarking that Professor Dana estimates the Tertiary period as being in length only one-fifteenth of the Mesozoic and Palæozoic combined, says: "On the estimate above given, founded on the dates of phases of high eccentricity [of the earth's orbit], we shall arrive at about 4,000,000 years for the Tertiary epoch, and sixteen million years for the time elapsed since the Cambrian [Lowest Silurian], according to Lyell, or sixty millions, according to Dana. The estimate arrived at from the rate of denudation and deposition (28,000,000 years) is nearly midway between these, and it is, at all events, satisfactory that the various measures result in figures of the same order of magnitude, which is all one can expect on so difficult and exceedingly speculative a subject. The only value of such estimates is to define our notions of geological time, and to show that the enormous periods of hundreds of millions of years, which have sometimes been indicated by geologists, are neither necessary nor warranted by the facts at our command; while the present result places us more in harmony with the calculations of physicists, by leaving a very wide margin between geological time as defined by the fossiliferous rocks, and that far more extensive period which includes all possibility of life upon the earth." (Wallace's Island Life.)

CHAPTER II.

(*Diagram II.*)

THE ACTION OF HEAT.

From the study of the effects of water in motion we naturally pass to that of heat, the second great geological agent.

We have already seen that the study of fossils and of the wearing effects of water, as manifested in the formation of thick beds of rocks, proves that the antiquity of the earth is very great. Our planet has had a history—a long period of development, when the earth, its waters and atmosphere were in a nebulous, chaotic state. The earth is a cooling planet. From a nebulous mass, perhaps 800,000 times its present size, it has condensed and cooled, and by revolution upon its axis has finally assumed its present shape, that of a sphere flattened at its poles.

Our earth revolves around the sun in cold, interstellar space with its own surface-physiognomy, its own oceans, its own atmosphere. The world has been compared to a living being, and it may be said in a sense to have organs, *i. e.* the oceans, winds and ocean currents and its atmosphere. Geology treats of the structure or anatomy of the earth, and its development; while in studying the action of its winds and currents we may be said to study its physiology. Moreover the earth has had a beginning, succeeded by a long, eventful history, abounding in critical periods, and, when we remember the great changes in the relative distribution of land and water-masses, with wonderful metamorphoses of form. So we may in a sense speak of the earth's embryology, or period of growth; its developmental history or evolution being as wonderful as that of an animal.

A most important element or working agent in this evolution of the globe has been heat or fire.

Volcanoes.—If we descend to the bottom of deep mines, it will be found that the temperature of the bottom is greater than at the surface. In general for every fifty or sixty feet of descent, the temperature increases 1° F. This, says Dana, in the latitude of New York would give heat enough to boil water at the depth of 8,100 feet, and at the depth of twenty-eight miles a temperature of 3000° Fahr., which is the fusing point of iron. The heat at the bottom of artesian wells is also in general greater than the surface temperature.

Moreover, the occurrence of volcanos and the widespread agency of heat or fire in former times indicate the existence of large areas of melted rock or lava in the earth.

Vesuvius is the best known example of a volcano. Our second diagram represents on the upper left quarter the eruption of this volcano in April, 1872, drawn from an instantaneous photographic view. The three great streams of fire, surmounted by clouds of vapor, extending down toward the Bay of Naples, and Resina, and other towns fringing the shore, are streams of molten lava which have overflowed from the crater. The glowing red-hot surface of the molten rock is reflected from the vapor-clouds overhanging it, and reflects an intense ruddy glow over the bay lighting up the water and the vessels. Over the volcano like a pall hang clouds of ashes which extend in all directions for a distance of fifteen miles from the peak.

We may be allowed to draw on our own experience, and quote from *Appleton's Journal* for 1873, the following account of an ascent made one month after this famous eruption, which took place April 26, 1872.

"After leaving the streets we begin the ascent of the mountain. The road winds through vineyards and orchards of mulberry and olive trees, scorched by the eruption of the 26th of April, their leaves hanging sear and withered—a witness of the sad destruction that fell with more or less severity on all plant-life for a distance of about thirty miles' radius from the volcano. The dust is ankle-deep; we pass beyond the walls, and now come out upon the lava-fields of the eruption of 1858. Walls of lava hedge in our track, and there is the strange and interesting sight of an expanse of lava, with its curling waves and troughs, like a petrified, inky, chopping sea. The road is comparatively new, rebuilt after the eruption of 1858. It winds in its devious way through the ridges and stony waves which rise higher and more broken; the peasants take short cuts from turn to turn, and, as they ascend, their picturesque forms stand out in relief against the sky.

"The Hermitage, a white-walled *auberge*, is reached by a quarter before nine. Here we leave our carriage, and walk for twenty minutes over a rocky, dusty, ashy path, past smoking rocks, and all the time sorely beset by the vociferous plagues whom we gradually distance. And now, as a Briton would say, we prepare for a bit of hard walking. The big ash-heap rises up steep and forbidding. The sirocco is still increasing in fury, whirling the light lava-dust in our ears and eyes. The hardest climbing is at the base, as here the ashes, whose particles are like coarse sand, but much lighter, are almost knee-deep. We flounder through it, often sliding back a step or two to three in advance. Stopping a moment to take breath, the inevitable man with his rope reiterates his proffers of aid in pulling us up, lowering his price at every halt. Not at all abashed by our emphatic signs of disdain at his offers, he officiously steps in between ourself and guide, jabbering his terms. It is best to let him walk there, as his feet beat down the ashes and make the walking easier.

"Half-way up the cone, the ashes somewhat diminish in depth; rough, rocky masses protrude through the waste of dust and ashes. To these we eagerly spring. Our interloper gives us up as hopeless, and turns back to prey on some more tractable traveller. Fillets of scraggy lava reach out their tortuous ridges to our aid; and, after an hour and twenty minutes of the severest toil, we stand upon the edge of the crater.

"The abyss, seemingly bottomless, is an inverted cone with smooth sides, a projecting rock here and there breaking the monotony of the slope. It looks like a colossal ant-lion's hole. The edge is two miles in circumference. We walk partly around it, pausing to look down; and, to sound its depths, roll a stone down, and watch it skipping and bounding in its headlong course, till it is lost in some fissure hidden from our sight. Our path leads us by pools of melted, bubbling lava, and over patches of smoking, crisp sulphur, whose choking fumes are whirled into one's face by the fitful sirocco, which now blows a stiff gale. An unusually well-rounded "bomb" is pocketed, and a pretty piece of lava, covered on one side with flowers of sulphur, is taken away as a memento.

"From a favorable point the crater which opened on the 26th of April can be seen, and the lava streams issuing from it and winding down the slopes for two miles away, with curling streams and cloudlets of smoke rising from them. While we pause to look down on the plains below, bordering the blue Mediterranean, with Naples in the distance, we fill in the map with the ruins of Pompeii, plainly in view; the site of Herculaneum; the towns of Torre del Greco and Resina, and, to the northward, the village of San Sebastiano.

"The best account of the last eruption, and many details in connection, were published after our ascent, by M. de Saussure, in the *Journal de Geneva* for the 7th of July. The writer is a descendant of the celebrated Alpine explorer of that name, and is himself a distinguished naturalist. He made the ascent two days before us, and spent a night at the observatory with Professor Palmieri, and had the advantage of hearing from the lips of an eye-witness—than whom, perhaps, no one is better qualified by his previous experience of former eruptions—a vivid narration of the terrors and sublimities of the last outburst. From his account we transcribe the following notes of facts not generally known to those who make a hasty ascent of Vesuvius. Of the magnificent but awful display, as seen from

Naples and its suburbs, the papers teemed at the time, and every one remembers the sad loss of life among the inhabitants of San Sebastiano, most of whom perished by being cut off by the lava-streams slowly closing around them after they had reached a supposed place of safety. It should be borne in mind that the streams flow but slowly, giving ample time for persons to escape from their houses.

"During the preliminary eruption, on the 24th of April, the lava rose to the top of the mountain, and filled the double crater to the brim; and, two days after, a stream of lava burst out from the southwest side, while a large stream from the Atrio overflowed from the crater itself, and divided into three currents, which assumed a southern, western, and northeastern direction, respectively. Thus relieved of its burden, the molten matter subsided into the depths of the crater, leaving no traces of its presence, as we particularly noticed, on the walls, since the long-continued and tremendous eruption of gas which succeeded had enlarged the opening of the crater by wearing away the projecting walls of lava and sweeping out the interior. This denudation of the rocks allowed De Saussure to quite distinctly perceive their structure, and to notice a number of lava-threads injected into the old fissure. He found it impossible to descend into the crater, as the slopes were terminated by vertical rocks which afforded no standing room. While writing this we notice the death of two men—one an American—who were let down by their guides into the crater. The ropes, probably worn away by the ragged rocks, failed to sustain them, and the guides could not rescue the foolhardy explorers.

"De Saussure regards the depth of the crater at about four hundred and twenty feet, and, on casual observation, it looks nearly as deep as the cone is high. The bottom seemed filled with *débris* and rubbish; but no flames could be seen, nor any adventitious cone. The volcano had fallen into complete repose. The only signs of activity were seen in quite numerous jets of white vapor, which escaped from the depths below as well as from fissures in the walls. Though when seen from Naples, Vesuvius nearly always seems surmounted by a vaporous smoke, this cannot be seen when one is near or upon the mountain.

"During an eruption multitudes of 'bombs,' or balls of melted lava, are thrown far up, sometimes four or five thousand feet into the air. Most of them fall back into the crater and around the edge. Thus, towards Pompeii, the sides of the mountain were strewed with them, from the size of the fist to that of a man's head. Sometimes, during an eruption, the shower is oblique, owing, perhaps, to the wind. Thus, in Pompeii, they often find large stones in the ashes which buried the town. When they are not to be seen on the side of the crater, it is because they have been covered up with ashes and volcanic dust.

"While thousands witnessed the eruption, and some who had driven out from Naples ventured too near for safety, and ran the great risk of being smothered by the ashes or choked by the gases, fortunately for science, one trained observer, Professor Palmieri, could from his watch-tower, situated a little over two thousand feet up the mountain, look down upon the blazing, seething, fuming lava-streams, and watch the successive events of the outbreak, as the volcano thundered and belched forth flame and smoke and clouds of acid gases and ashes, which enveloped his habitation and darkened the sky. The suffocating heat radiated from the burning lava became for a time almost insupportable, and he was obliged to enclose himself hermetically, so to speak, by the shelter of the counter-irradiation of heat from burning sheets hung around; and even then the ashes were driven by a steady wind through the seams of the windows, which rendered it difficult to breathe. Then, during the last day of the eruption, there fell a shower of volcanic gravel (*lapilli*), which broke the panes of glass, and subjected him to the danger of exposing his apartments containing his instruments to the whole force of the wind.

"How the eruption appeared to those at a distance may be best told in the words of Mr. Scrope, a veteran student of volcanoes. He says: 'Suddenly, on the morning of the 26th of April, a violent earth-shock was felt throughout the area of the mountain, and fearful detonations and incessant rumbling noises, accompanied by other shocks, were heard to proceed from the summit, which, at the same time, threw up a lofty fountain of steam and stones. A paroxysmal eruption had evidently commenced. The subterranean energy residing in the lower depths of the volcanic forces had increased to a point at which the minor extravasations and ejections that had been so long going on from the summit, could not suffice for its relief. Violent ebullitions broke forth at some point in these lower recesses of the volcanic chimney, and, with terrific eructation, the evacuation of the contents of all its upper portion began. Shock succeeded shock, till those who looked at the mountain from a distance saw the colossal trunk of the pine-cloud reaching to a height of many thousand feet above the mountain-top, in the usual double-ascending column—one of white, globular masses of vapor, the other of scoriæ, black by day, but red-hot by night; while streams of incandescent lava gushed forth from several openings on the flank and at the base of the great cone. . . . The roarings and shocks of the detonations were especially loud and fearful, as heard and felt even at Naples, obscuring the light of the sun, and giving to the atmosphere the appearance of a London smoky fog. This fine dust fell in the streets and on the house-tops to the depth of an inch or more, and, heavy rains accompanying its fall, made the circumstance more disagreeable.

"'The stream of lava which broke through the side of the mountain was over three thousand feet wide. The principal stream followed the valley of the Fosso de la Ventrana, and ran a distance of nearly a mile in two hours. As it passed below the observatory, the lava was seen to puff up in places, and break out in small eruptions, discharging jets of steam and ashes. This stream passed like that of 1858, exactly between the villages of Massa and San Sebastiano, carrying away a part of the houses, and ending by separating, one fork stopping south of Cercola, while the other extended in the direction of San Georgio.' 'The imagination,' says De Saussure, 'cannot conceive how such a mass of matter could escape in one day from a single focus, and spread itself over a course of over four miles.'

"The lava thrown out is the same in appearance as the older lavas, though a little more scoriæceous than that of 1858.

"The effect of this eruption, besides opening a new crack running north-northeast and south-southeast, has been to lower the summit, and render the peak blunter. Thus the contour of the mountain changes with each eruption. When the ill-fated Pliny gazed upon the eruption of the year 79, and beheld the clouds of ashes and stones which overwhelmed Pompeii and Herculaneum, Vesuvius had no cone, its summit then being a flat table-land. Since then the mountain has gradually grown to its present height. Looking down into the crater, we could see the beds of lava inclining away from the vent, and thus understand how the mountain has been built up by successive overflows from the vast reservoirs beneath, as an ant builds up its little cone of dirt by repeated upheavals of the soil from the passage below.

"The lava-streams two miles away from the crater appeared to be still smoking, as if portions had not become cooled; but, says De Saussure, these were smoke-vents or *fumaroles*, connected with the melted portions at the bottom of the stream. The lava had become cool on the surface, and the heat that it gave out was borrowed from the sun.

"He also states that there was no burning lava at the bottom of any crevice that he examined, though the lava certainly preserved its heat under the superficial layer, as the great number of *fumaroles* attested. The emanations of vapor escaped, for the most part, from small holes which communicated by fissures with the partially melted lava, below. Around each of these foci prevailed a strong odor of hydrochloric acid, while other *fumaroles* emitted only watery vapor or warm air. They are, in short, as De Saussure says, the successive phases that indicate the different degrees of cooling of the lava up to complete frigidity. These gases and warm vapors expelled from the lava are charged with numerous substances, and become the sources of mineral deposits, which excite the curiosity and wonder of tourists. Here, in fact, is a laboratory, where the mineralogist may behold the formation of the objects of his studies, and learn more of metallurgy and the mode of formation of minerals than by years of ordinary observation. On the surface of these cooling lava-streams are formed, in especial abundance, crusts of sea-salt; and it is a curious quality of this burning lava of retaining a great amount of water and salt, which does not escape in the process of cooling. It should be remembered that all rocks contain water, and especially those earliest lavas, the granites, our hardest rock. Here the student can witness the passing off of the water in the form of vapor, and see, as a result of the process, the solid crystals of salt remaining behind. A similar efflorescence appears, according to one observer, even on the ashes spread over the plain, and which also disengage hydrochloric acid. The first rains that set in after the eruption dissolved this frost-like efflorescence; and, on the 12th of May, but feeble traces of it remained, except on the under side of blocks of lava, where the sun could not dissolve it. It formed, however, in the *fumaroles* and on the great deposits of ashes on the cone; and, as late as the 10th, the summit of the mountain, seen from the observatory, appeared as if powdered with snow. From the presence of this salt, it is reasonably supposed that there is a subterranean communication in the crater with the sea.

"To sum up; the more striking phenomena attending the eruption of last April were its suddenness and unusual violence and brevity, and the dead slumber into which the volcano soon afterwards fell. The form of the mountain was changed, as the edge of the old crater was somewhat worn away, thus blunting the top of the cone, while a vast transverse ridge, much longer than broad, divides the cone into two main compartments, while the third crater is situated at the north of the two larger ones.

"Peering down into the crater, one could see how the successive overflows were arranged in beds, dipping away on all sides from the crater. And this is how mountains grow. In this way not only Vesuvius, but its neighbors, have risen, and the plateau on which they stand. Add to this a secular rise of the land, which means that the earth's crust is being thrown up into wrinkles, and we have mountain-chains formed. Such is the history of the Alps, of the Rocky Mountains and the Andes. These mountain ranges are the frames in which continents are set. Thus the results of a day or two's excitement on the part of old Vesuvius give us a clew to the mode of formation of continents."

9 We have seen that a volcano is in general a conical mountain with a funnel or cup-shaped opening or crater from which melted rock or lava overflows. Its action may be constant or intermittent. A volcano is said to be extinct when no eruption has taken place within historic times. There are many extinct volcanos on the Pacific coast of America; the best examples being Mount Shasta, in Northern California, which is 14,400 feet high, and Mount Hood, in Oregon, at the Dalles. On the summits of both of these volcanoes are hot springs giving out steam and sulphurous gases, which shows that they have only recently, perhaps within a few centuries, become extinct, and that they may possibly again break out. Farther north are the volcanic snow-capped cones of Mount Adams, Mount St. Helens, and Mount Renier, while in northern Alaska Mount St. Elias is 19,000 feet in height, the highest mountain in North America. From its lofty summit glaciers descend into the sea.

In Central America there are numerous active volcanos, most of them of great age, while the famous volcano of Jorullo was thrown up in a single night, Sept. 28, 1759. The other Mexican volcanos are the Colima, the Nevado de Tolima, Orizaba and Tuxtla, while near the city of Mexico rise the volcanos of Istacihuetl and Popocatepetl. But these are all inferior in height, above the surrounding plateau, to Mount Shasta, which rises 12,000 feet above the plain, a majestic cone, its snow-capped peak cleaving the clear Californian sky. In Central America, south of Mexico, are thirty burning mountains, nearly all famous on account of the wide-spread devastation to life and property which have attended their eruptions.

Besides lava, which on cooling and under pressure becomes a heavy, dark, crystalline rock, when it is called *trap rock, basalt* and *greenstone,* great clouds of ashes are thrown out and form beds of *trap ash* or *volcanic ash,* often found in the West underlying lava-beds. When the beds of light and porous scoriæ and ashes have the small cavities or vesicles filled with various minerals somewhat of the form and size of almonds, the rock is called *amygdaloid.*

Besides volcanic dust and ashes, large cinder-like fragments, like the clinkers in furnaces, called *scoriæ,* and pumice stone (which is a glassy lava distended by escaping gases) are thrown out, and if the volcano is situated on the coast, the pumice stone floats off upon the sea. Another volcanic product is *obsidian,* a substance like the glass of junk-bottles, usually black, though it may be red or green or blue. It is nearly as pure quartz as window-glass, and occurs in Montana in the Yellowstone Park in beds, also at various points in California.

Still another substance formed on the surfaces of volcanos is tuff or tufa. Owing to the condensation of steam emitted from the vent or crater, heavy showers of rain follow eruptions, and the falling dust and ashes mix with the water, forming streams of muddy paste. This, on hardening, forms tuff. In the Andes very extensive streams of mud thus appear to issue from vents and to inundate the plains below.

When a great stream of lava or basalt cools off, it contracts and forms cracks, which enclose six-sided masses or columns. Such a columnar, prismatic structure is seen in the basalt of the Island of Staffa, out of which the sea has worn Fingal's Cave. These six-sided, or prismatic columns are often to be met with in the Far West. They occur in the Yellowstone Park, and the artist has introduced a few such columns in the picture of the Geysers on the right side of the Diagram. (See also Fig. 1.)

The cooling of lava streams, as Judd states, is a very slow process; it may require many hundreds, or even thousands of years, although it rapidly cools at the surface so that one may walk over it.

When lava fills fissures in the rock surrounding, it forms what is called a dyke. These so-called veins or dykes are common in New England, as well as in the West. We have seen most extensive and striking series of them on the coast of Labrador.

The grandest exhibitions of lava overflows in this country are in eastern Oregon, where 20,000 square miles of stratified rocks are covered with lava. The vast sandy desert of the Snake river is underlaid by a hard black trap rock, through which the Snake river has worn the rapids at Taylor's bridge on the Montana Stage road, as well as the wonderful Shoshone and American falls farther west. These overflows of lava have probably here, as Geikie states, escaped from innumerable fissures in the earth's surface; but after having travelled over this Upper Snake region, and also passed through the Dalles of the Columbia river, and seen the enormous overflows of lava which have built up the Cascade range, I am unable to agree with Professor Geikie that volcanic energy was not exhibited on a scale greatly transcending any eruptions of historic times. It will probably be found that the lava fields of the Cascade range extended near to the head waters of the Snake river, and that

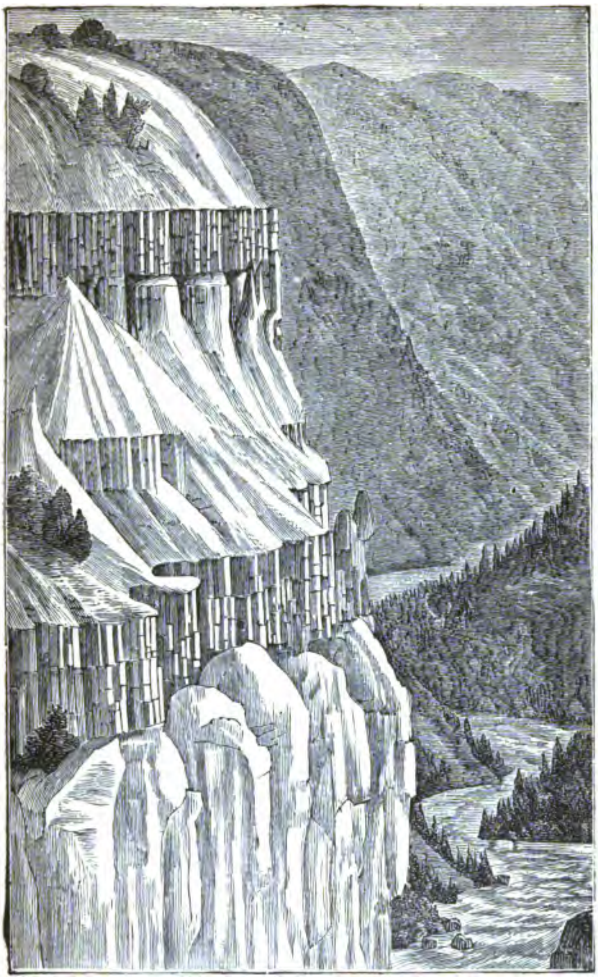


Fig. 1.—Basaltic Columns on the Yellowstone River.—*From Hayden's Survey.*

the fissure-eruptions of the Snake River plains eastwards tool place at the same time as those which built up the Cascade range. As we ascended the cascades of the Columbia, and had nearly passed through the gorge, at a point before the town of Dalles heaves in sight from the deck of the steamer, the towering cliffs from 1,500 to 2,000 feet high on the northern side of the bend of the river presented the most magnificent *exposé* of lava beds that exists on the globe. Great beds hundreds of feet in thickness of more or less columnar basalt were seen to slope eastward. The vast natural section cut through the heart of the Cascade range by the Columbia, showed that from the river's edge to the summit of the mountain range, this had, unlike most mountain ranges of the older parts of the country, been built up by successive overflows of lava; as though it had been a continuous series of volcanic craters merged together and all vomiting forth streams of lava which flowed down their slopes. Mount Hood, which stands sentinel over the scene, and Mounts Adams and St. Helens, north of the Dalles, peaks from 10,000 to 12,000 feet in height, are later craters and were probably not witnesses of the intense vulcanism which reigned supreme during Tertiary times. Ascending the Columbia to a point near Walla Walla, the lava beds continue on each side of the river, and without doubt extend south and east, following the course of the Snake river into the eastern border of Idaho.

A word or two concerning the destructive effects of volcanic eruptions. In the year 79 after Christ, the cities of Pompeii and Herculaneum were destroyed by storms of ashes and *lapilli*, or fine grains of scoriæ like marbles or peas, with clouds of sulphurous gases thrown out by Vesuvius. Ætna in 1667 destroyed fourteen towns and villages. The eruption of Timboro, in the island of Sumbawa, destroyed in 1815 nearly 12,000 person. "In the island of Sumatra," says Reclus, "500 miles to the west, the terrible explosion was heard, and, for a radius of 300 miles around the mountain, a thick cloud of ashes, which obscured the sun, made it dark like night even at noonday. This immense quantity of *débris*, the whole mass of which was, it is said, equivalent to twice the bulk of Mount Blanc—that is, 2,358,000 millions of cubic yards(?)—fell over an area larger than that of Germany. The pumice-stone which floated in the sea was more than a yard in thickness, and it was with some difficulty that ships could make their way through it." Clouds of ashes were carried 870 miles southward to Borneo. The volcano of Skaptar Jökull destroyed 1,300 human lives and 150,000 domestic animals. Volcanic eruptions are, however, not nearly so destructive to human life as earthquakes, but when we learn that in the year 1880 21,990 persons in India died from the bites of snakes and attacks of tigers, the balance in favor of Vulcan's misdeeds is very considerable.

To give some idea of the frequency of eruptions, those of 1878 may be enumerated. There were twelve recorded. Vesuvius had limited eruptions; in the southern part of South America there were active, but unknown volcanoes in a state of activity. The volcano of Isluga in South America destroyed four villages, and Cotopaxi was active. The most violent eruptions occurred in Peru and Bolivia. The eruptions of Tauna in the New Hebrides lasted four weeks. There were eruptions in the Aleutian islands. Mount Hecla maintained its reputation as an active, energetic volcano; the town of Esmê on the Bosphorus was destroyed, and there were eruptions of mud volcanoes in Palermo, Sicily.

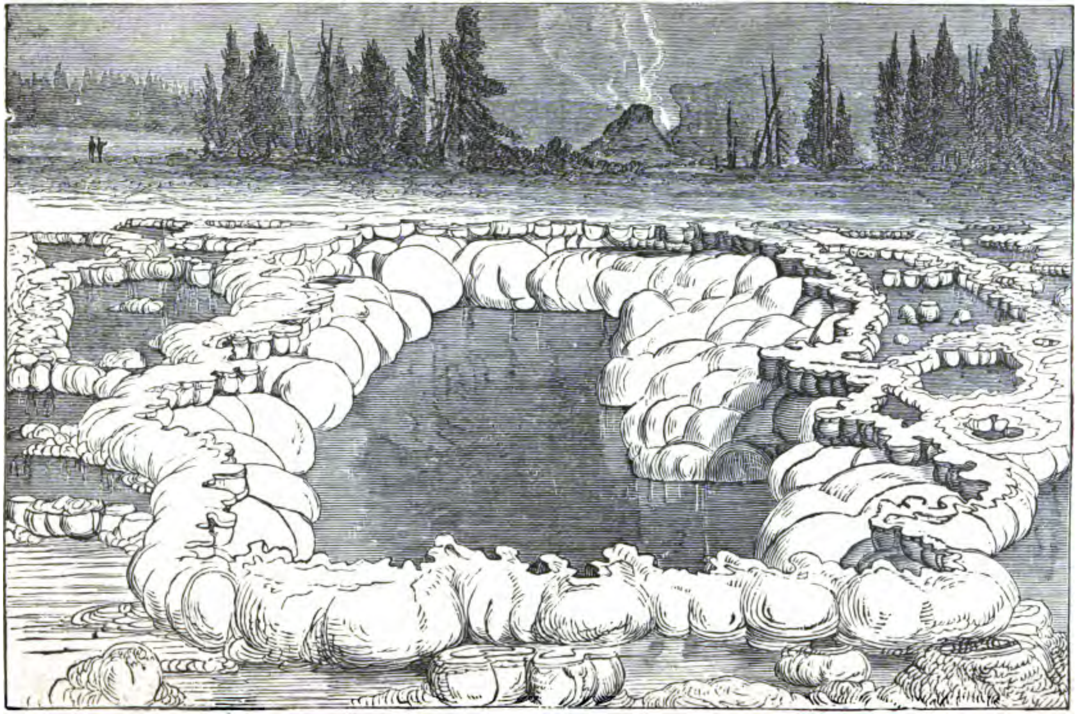
Geysers.—Among the subordinate volcanic phenomena are geysers. These are periodically eruptive hot springs. They occur in Iceland and New Zealand, but are particularly numerous and large in the Yellowstone Park. The geysers in Iceland are quite numerous, and the Great Geyser has been studied more than any other. The pool or crater is 56 feet in diameter, situated on a mound 30 feet high. From the bottom of the basin descends a funnel-shaped pipe 18 feet in diameter at the top and 78 feet deep; the basin and tube are lined with silica, deposited by the hot water which holds it in solution. In the intervals between the eruptions the basin is filled to the brim with water of a temperature of 170°-180° Fahr.

Just before an eruption, sounds like a cannonading are heard; and bubbles rise and break on the surface of the crater. There is a bulging of the surface of the crater which overflows the basin, when the entire mass of water in the tube and basin is shot 100 feet high, and followed by the escape of steam. The eruptions have been known to occur regularly every ninety minutes and generally last six or seven minutes.

Our diagram represents the Bee Hive Geyser of the Yellowstone Park, that wonderful theatre of minor volcanic events, where there are said to be nearly 10,000 geysers and hot springs, active and extinct; where there are thousands of mud volcanoes or rather volcanets; where there are the most extensive beds of black and variegated obsidians; vast fossil forests, and where the Yellowstone river plunges by two sublime cataracts into cañons whose vast depth and richly variegated rocky walls have altogether rendered the National Park the most interesting region on the continent to the observer of nature.

We have brought together in the diagram, the Bee Hive Geyser, throwing a jet of water over 200 feet high, the fossil forests (on the extreme left), and on the right a few columns of columnar basalt, all evidences of the action of fire, although in nature the geysers are many miles from the fossil forest. The Park, which has been explored and mapped by Dr. Hayden's survey, abounds in these traces of spent, exhausted volcanic action.

Geysers, mud volcanets, fumaroles, carbonetted springs and hot springs of a temperature of from 160° to 200° Fahr., are the sequelæ of volcanic eruptions. Prof. F. V. Hayden, who has given the fullest accounts of these geysers in his reports for 1871 and 1872 of the geological surveys of the Western Territories, states that the Grand Geyser throws up a column of water six feet in diameter to a height of 200 feet, while the



CRATER OF THE OBLONG GEYSER, YELLOWSTONE PARK, SHOWING THE SILICIOUS DEPOSITS ON THE EDGE.—*From Hayden's Survey.*

steam ascends a thousand feet or more. An eruption takes place every thirty-two hours and lasts about twenty minutes; when quiet the temperature of the water is 150° Fahr. The Giantess throws up a column twenty feet in diameter and sixty feet high, and through this large mass projects five or six lesser jets to a height of 250 feet; an eruption occurs every eleven hours, and the geyser plays twenty minutes. The Bee Hive Geyser, whose crater, as seen in the diagram, is quite regular and shaped like a bee-hive, being three feet in height and five in diameter, throws up a jet exceeding 200 feet in altitude.

The fossil forest of the Yellowstone Park is a mountain composed of layers of a greenish sandstone containing the trunks of silicified trees, some standing and others fallen. The trees have been turned to stone by the water from hot springs containing silica in solution.

26 *Earthquakes.*—These are the most terrible and widespread of all volcanic agencies, and no part of the world is free from these convulsive movements of Old Vulcan. On an average there are known to have been, since 1843, 575 earthquakes a year. Mallet has collected the records, since the earliest times, of 6,830 earthquakes which have occurred over a period of 3,456 years previous to 1850; but of these, 3,240 occurred during the last fifty years. Our earth, therefore, is constantly shaking somewhere.

Earthquakes usually attend volcanic eruptions, but many of them are not connected with volcanic energy. Volcanic eruptions of the explosive type where craters are blown to pieces, as in the East Indies, are preceded or accompanied by earthquakes. Moreover, earthquakes which have been troubling a region for a long time often cease when an eruption takes place in a neighboring volcano. Also a sudden cessation of the usual volcanic eruptions will often bring on shocks. The terrific earthquake which destroyed Rio Bamba, in 1797, when 40,000 persons perished, took place immediately after the eruptions in a neighboring volcano stopped. The earthquake which in

1812 destroyed the town of Caràcas, ceased as soon as St. Vincent in the West Indies, 500 miles distant, began its eruptions.

The causes of earthquakes are sudden movements in the interior of the earth, producing jars, which by what seem to us as wave-like motions reach the earth's surface. During an eruption a mountain may be, says Judd, in a constant state of tremor. "These earthquakes are not, as is commonly supposed, actual upheavings of the earth's surface, but are vibrations propagated through the solid materials of which the earth is built up. We cannot stamp our feet upon the ground without giving rise to such vibrations, though our senses may not be sufficiently acute to perceive them. The explosive escape of steam from a crack is a cause sufficiently powerful to produce a shock which is propagated and may be felt for considerable distance round."

Earthquake shocks, says Judd, so far as is at present known, never originate at greater depths than thirty miles from the surface, and "in some cases the focus from which the waves of elastic compression producing an earthquake proceed, is only at the depth of seven or eight miles."

It appears that the earth-waves travel at about the same speed as waves of sound transmitted through granite, which is an excellent conductor, and this rate is about nineteen miles a minute.

The motion of earthquakes may be undulating or rocking, like that caused by throwing a stone into a pond, the waves spreading from a centre to a great distance; or the motion may be a whirling one, as seen in the great earthquake at Lisbon which twisted off or moved around church towers and other lofty structures.

A large number of earthquakes originate under the ocean, and they give rise to the "great sea-wave," that terrific accompaniment of earthquakes felt on the coasts of volcanic regions.

The following facts throw light on this intricate subject, and on the rapidity with which the tidal wave is propagated over the earth. The great tidal wave which followed the earthquake of Lisbon, in 1755, was also felt at Ireland and at the West Indies. At Japan, in 1854, the tidal wave thirty feet high in 12¼ hours reached San Francisco, where the wave was eight inches high. August 13, 1868, a tidal wave fifty to sixty feet high, which swept the coast of Peru, in three hours reached Coquimbo, 800 miles distant; in twelve hours reached Honolulu, 6,580 miles away, and the next day had travelled 10,000 miles to the Japanese coast. The same wave was also observed on the coast of California, Oregon and Alaska, over 6,000 miles in one way, and on the Australian coast, nearly 8,000 miles in another direction.

Relative changes in level of Land and Sea.—The earth is more unstable than is popularly supposed to be the case. Nearly the whole coast of Norway and Sweden has been slowly rising for thousands of years past. Old sea-beaches, 600 feet above the sea-level, with sea shells, barnacles, etc., occur from fifty to seventy-five miles inland. This rising area of Scandinavia is a thousand miles in extent, and the rate of elevation is supposed to be 2½ feet a century.

On the opposite shores of the Atlantic we have observed along the north-eastern coast of Labrador splendid exhibitions of raised, terraced beaches, which, owing to the scantiness of the vegetation on those Arctic shores, appear as fresh as if the waves had retreated from them but yesterday. Beaches 300 to 400 feet high slope down to the sea, at the edge of which are old sea bottoms abounding in fossil shells, like those now existing in the ocean at a depth of from 300 to 600 feet. An intelligent captain of a whaler has described to us similar terraced beaches on Resolution Island, on the northern side of Hudson's Straits. Also on the Lower or East Savage Island he saw a plain of soft clay elevated fifty feet above the sea, into which he "sank knee-deep," and perceived in it numerous "clams and mussels," and also the skeleton of a boar-head whale stranded upon the surface. This ancient sea-bottom was flanked by a raised beach from thirty to forty feet in height. At Sir Thomas Roe's Welcome, he describes the beaches as being higher than any observed southward, and he also noticed clay-banks, containing shells, raised above the present level of the sea. Professor Hind has also noticed some remarkable raised beaches fifty miles in the interior of southern Labrador, and 370 feet above the sea-level. In the Arctic regions, especially in northern Greenland, there are similar raised beaches 500 and 600 feet above the sea, with fossil shells. The coast of Labrador and Newfoundland is supposed to be still rising at a very slow rate.

On the other hand, the coast of southern Greenland is slowly sinking along a space of 600 miles. Ancient buildings erected by the Greenlanders, and rocks formerly known by them to have been above the surface of the sea, but now submerged, are the evidences of this depression of the coast. Hence there is in Greenland a see-saw movement of the land going on.

Nearer home, the coasts of New Jersey, of South Carolina and Georgia are slowly sinking, the evidence being buried cypress swamps below low-water mark, while the coasts of Florida and the Gulf States, and the West Indian islands are slowly rising. The deltas or low countries at the mouths of the Mississippi, of the Ganges and the Po, and other large rivers are sinking areas.

It is not known that these cases of slow gradual elevations and sinkings of shore lines are connected with earthquakes, but in volcanic regions around the Mediterranean the coast is well known to be locally either rising or sinking, as at Baiæ, near Naples, Venice, Candia and in Greece. Says Reclus, "Like Sicily and several parts of the coasts of Italy and Greece, a considerable number of islands—as Malta, Rhodes and Cyprus—are surrounded with circular terraces more or less elevated above the level of the sea, and composed of sandy or calcareous rocks of recent formation. The northern portion of the Island of Crete has risen more than sixty feet during the present geological period. A study of the shores of Asia Minor proves that there also the ground has continued, since man inhabited that region, to rise with a rather rapid movement. During historic times this part of the continent has gained a considerable belt of land at the expense of the Ægean sea. It is not the alluvium of the rivers, or the matter washed up by the sea, which has caused this increase of the land, for the Anatolian rivers are very inconsiderable, and the water which bathes the coast cannot, on account of its great depth, throw up much sand. It must therefore, be in consequence of a slow upheaval of the earth's crust that the ruins of Troy, Smyrna, Ephesus and Miletus have gradually become more distant from the coast, and appear to be receding still further inland. From the same cause so many islands in the Ægean sea which were once separate are now united, or are connected with the mainland, and form headlands or hills surrounded by low-lying plains. The testimony of ancient authors is unanimous as to these encroachments of the shores. Thus it is said that the two halves of Lesbos, Issa and Antissa have become united, that the bays have been converted into inland lagoons, and that various islands have joined on to the mainland at Mindus, Miletus, the Parthenion Cape, at Ephesus, also at points near Halicarnassus and Magnesia. At the time of Herodotus, the mountain of Lade, not far from which the Ionian galleys fought a battle with the Persian fleet, was an island; at the present day it forms part of the mainland, and stands in the midst of the plain of the Meander. Since the date of Strabo and Pliny, several other islands have similarly become headlands. ("The Earth.")

Other examples are mentioned by Reclus. The southern and northern shores of Asia Minor are rising. "During the present geological period the area of the Euxine has been diminished, and, according to the traditions of the Crimean Tartars, it is still diminishing. Banks of modern shells have been left by the sea at considerable heights on the hills of Thrace and

Anatolia; round the Crimea, salt lakes, stagnant marshes now exist far inland in the place of former gulfs." Reclus says that beyond doubt the Caspian Sea, the Sea of Aral, and all those innumerable sheets of water which are scattered over the steppes, were separated from the Euxine and the Gulf of Obi by a gradual upheaval of the continent. "The plains are still covered with salt and marine remains. The inland seas and the scattered lakes are still inhabited by seals, and their fauna altogether presents an essentially oceanic character." On the coast of Syria and Palestine, the shores of the Gulf of Iskanderoun are rising, but at Beyrout a tower is shown which is sinking in the water. The former island of Tyre, the site of the once busy maritime city, is now connected with the continent. "Lastly, Kaisarieh, and some other towns in Palestine, are included in an area of subsidence, as is proved by the remains of fortifications which are now visible below the level of the Mediterranean."

26. *Mountain-Building.*—What has been said as to the changes in the relative level of land and sea, shows that the earth is not the firm, stable land popularly supposed, but that it is only less unstable than water. And as we shall now see, such movements as these renewed at intervals along coast lines result in the elevation of such coast lines for many thousand feet; the great plateau thus formed being during the slow, secular, intermittent rise, carved by running water into ranges of mountain peaks.

But before we theorize, let us look at the facts supporting the statement we have just made. In 1822, after an earthquake, the shores of Chili and Patagonia were elevated from two to seven feet. Again, in 1835, following an earthquake which shook the coast of South America over an area of 600,000 square miles, the whole coast line of Chili and Patagonia was elevated from two to ten feet above the sea-level. There are also said to be old beach lines from 100 to 1,300 feet above the sea extending for 1,200 miles along the coast of the southern extremity of South America. Now it is believed that the force which raised the land was also the cause of the accompanying earthquakes.

But there are proofs that the coast of Peru has not only shared in this rise at successive periods, but that it has been elevated at least 3,000 feet above the sea. This proof consists in the fact that sea corals of species identical with those now living in the adjacent seas have been found by Mr. A. Agassiz, at Tilibiche, Peru, at a point from 2,900 to 3,000 feet above the present sea-level. These corals were found attached to the surfaces of rock on a ridge parallel to the coast. Moreover, the presence of extensive saline basins at an elevation of over 7,000 feet above the ocean suggests that they may have been old ocean basins. Also the existence of species of "a truly marine family of little shrimp-like crustaceans, at a depth of 66 fathoms in Lake Titicaca, indicates that this lake, which stands 12,500 feet above the sea-level, may possibly have been a remnant of the sea, cut off by the elevation of the coast-ranges lying between it and the present seashore." However this may be, geologists feel justified in supposing from the above facts, that the Andes, from Panama to Cape Horn, have been slowly and at intervals elevated above the ocean level, and that in this way a large proportion of the continent of South America has been added to the older eastern Brazilian portion. We thus see how continents and mountain chains have been probably elevated and become dry land.

In all probability the Cordilleras of North America arose by successive stages, by sudden elevations following long pauses and intervals of rest; for there are terraces extending from California to Alaska, and the coast is known to be still slowly rising.

Rock-making from sand, mud, etc.—All rocks are either stratified or unstratified. An example of stratified rocks are common roofing-slate, coal shale, sandstone and mica schist, etc. These are simply rocks which were originally masses of sand, and mud or clay, which have been changed or metamorphosed into slate, schist or gneiss. That soft shell-limestone may be thus changed or transformed into statuary marble is shown in several localities in the Alps, and the cause of the alteration is the heat given out by the proximity to, or the squeezing into cracks and fissures of the sedimentary rock, of melted lava.

The latest views regarding metamorphism are well expressed by Mr. Judd in his recent interesting book on Volcanoes. He says: "The eruption of these great masses of incandescent rock, impregnated with water and acid gases, through strata of limestone, sandstone, clay, coal, etc., may be expected to produce striking and wonderful chemical changes in the latter. Nor are we disappointed in these anticipations. Whenever we examine the sedimentary materials around volcanic vents, we find that, in contact with the once-fused materials, they everywhere exhibit remarkable evidences of the chemical action to which they have been subjected. The limestones are converted into statuary marble, the sandstones pass into quartzite, the clays assume the hardness and lustre of porcelain, while the coals have lost their volatile ingredients and assumed a form like coke or graphite. And these changes are found to extend in many cases to the distance of many hundreds of yards from the planes of junction between the igneous and the sedimentary materials.

"Among the most interesting effects resulting from the extension of masses of incandescent rock, charged with water and various gases, through beds of limestone, clay, sandstone, etc., we may mention the production of those beautiful crystalline minerals which adorn our museums and are so highly prized as gems. By far the larger part of these beautiful minerals have been formed, directly or indirectly, by volcanic agencies.

"Those gems and beautiful minerals are, for the most part, substances of everyday occurrence, which entirely owe their beauty to the crystalline forms they have assumed. The diamond is crystallized carbon, the ruby and sapphire are crystallized alumina, the amethyst and a host of other gems are crystallized silica; and in almost all cases the materials of gems are common and widely diffused; it is only in their finely crystalline condition that they are rare and therefore valuable.

"Crystals are formed during the slow deposition of a substance, either by the evaporation of a liquid in which it is dissolved, by its volatilization, or its cooling from a state of fusion. In many cases it can be shown that the formation of large and regular crystals is aided if the work goes on with extreme slowness and under great pressure. By sealing up various substances in tubes containing water which can be kept at a high temperature, minute crystals of many well-known minerals have been artificially formed by chemists. Part of the water converted into steam has formed a powerful spring, which, re-acting upon the remainder of the liquid in the tube, has subjected it to enormous pressure, and under these conditions of extreme pressure and temperature, chemical actions take place of which we have no experience under ordinary circumstances. The experiments of Mr. Hannay seem to prove that when carbon is separated from certain organic substances at a high temperature and under great pressure, it may crystallize in the form of the diamond. And the recent discovery of diamonds in the midst of materials filling old volcanic rents in South Africa seems to show that this was in many cases the mode in which the gem was originated. Even under the conditions which prevail at the earth's surface, however, minute and unnoticed chemical actions taking place during long periods of time, produce most remarkable results. This has been well illustrated by M. Daubrée, who has shown that in the midst of masses of concrete which the Romans built up around the hot springs of Plombières and other localities, many crystalline minerals have been formed, in the course of 2,000 years, by the action of the waters upon the ingredients of the concrete. . . . .

"But it is not only the finely crystallized minerals and gems which we owe to volcanic action. The various metallic minerals have nearly all been brought from deep-seated portions of the earth's crust and deposited upon the sides of rock-fissures by the agency of the same volcanic forces. It is these forces which have, in the first instance, opened the cracks through the solid rock masses; and, in the second place, have brought the metallic sulphides, oxides, and salts—either in fusion, in solution, or in a vaporized condition—from the deep-seated masses within the earth, causing them to crystallize upon the sides of the fissures, and thus form those metallic lodes and veins which are within reach of our mining operations.

"There is still one other important class of minerals which owe their existence, though indirectly, to volcanic agencies. The cavities of igneous rocks, especially the vesicles formed by the escape of steam, constitute, when filled with water, laboratories in which complicated chemical re-actions take place. The materials of the lava are gradually dissolved and re-crystallized in new combinations. By this means the most beautiful examples of rock minerals as the agates, the onyxes, the rock-crystals, the Iceland-spars, and the numerous beautiful crystals classed together as 'Zeolites' have been formed."

It will be seen that the larger part of the volcanoes, active and extinct, as well as earthquake centres, are situated along coast lines, as on the Pacific coast of North and South America, and the East Indian and West Indian Archipelagoes. Connect this circumstance with the fact that thick beds of sediment are also deposited along coast margins, and we have a clue to the mode of formation of mountain chains.

30 Take for example the probable mode of origin of the Appalachian mountain chain from the Green Mountains to the end of the range in northern Georgia. The rocks in this range are 40,000 feet thick, and were once sand, clay and mud, which have been changed by heat and pressure into sandstones, limestones and slates. Now these sediments had been accumulating

for ages and ages, the ocean bed sinking gradually under their great weight, until at the end of the Palæozoic era the whole mass was slowly folded up into great wrinkles or ridges, and the whole Appalachian plateau was raised to a much greater height than now. During this comparatively sudden process of upheaval, portions of the mass fell down into the earth's crust and others remained stationary, so that there were great cracks and "faults" produced. Meanwhile it is supposed by Prof. G. L. Vose, in his "Orographic Geology," that the motion of these great masses gave out a certain amount of heat, and as the sediments contained a small percentage of water, the action of the heat and water combined with the pressure of the upper on the lower part of the mass, hardened and baked or metamorphosed the whole mass. The last step in the formation of the Appalachian mountain chain was the erosion by rain and rivers of the great wrinkles or ridges such as the Blue Ridge, Alleghany Ridge and the Cumberland Mountains, until the individual mountains were carved out of the main plateau. Such in brief is the theory of the process of mountain-building.

The facts which support such a theory are numerous. It will be seen, however, that mountains are not, as is popularly supposed, upheaved violently and suddenly, but that the history of a mountain chain is a long one. For ages and ages beds of sand and mud accumulate at the bottom of a comparatively shallow sea, one rich in animal life, shell-fish and coral-builders, whose hard parts breaking up, form a limestone mud like that now fringing the coasts of Florida and the West Indies to a depth of many fathoms. At length after millions of years the weight of these accumulations becomes so great that the crust of the earth gives way and the lateral forces hitherto held in abeyance re-act, and the whole mass is folded and crumpled, a part falling into the bowels of the earth, the larger part being upheaved and forming a great ridge or plateau. Thus through long periods of preparation, in the fullness of time a crisis comes, and the mountain chain is upheaved; this latter process even not being a sudden one, but consisting of sudden rises with long pauses between them. During the process, even, of upheaval, as soon as the great plateau appears above the ocean, rain storms produce rills and brooks, the ocean leaves mediterranean seas and land-locked lakes, whose waters gradually evaporate their salts, becoming fresh, although as in the Great Lakes of North America, the lakes of Sweden and of Italy and of Peru, there may be left species of marine shrimps, etc., relics of the ocean life from which they have become separated.

We shall see in the succeeding chapter, and this will be the thread of our narrative, how by the upheaval of one portion after another, our North American continent has been gradually built up. We shall see that the north-eastern part of America was first converted into dry land, that the mountains of Labrador and the hills along the northern bank of the St. Lawrence river, called the Laurentian hills, and the Adirondacks, were the first to become dry land. These mountains were probably much higher than now, and as they were worn down the sediments thus formed became ultimately the materials out of which the Green Mountains were formed. The White Mountains and the rest of the Appalachian mountains were then added to the small island-like continental nucleus. Finally the Rocky Mountains were upheaved, and out of their waste, eroded material the Sierra Nevada was formed and finally upheaved, and last of all the low Coast Range of California. Thus each mountain chain has a distinct history, and what an eventful history it is!

Moreover, the mountains rising out of different mountain chains have each a different physiognomy. The oldest mountains are the lowest, and their peaks are often flattened and rounded. On the other hand the newest mountains, such as the Alps, the Himalayas, the Sierra Nevada, are the loftiest and run up into the sharpest peaks.

We have said that as soon as the mountain chains or plateaus appear above the ocean, and the waters of the sea drain off, the drainage system, originally valleys lying between the ridges, with cross valleys connecting the larger ones, at first perhaps formed arms of the sea, deep bays and shallow estuaries, which finally became the beds of rivers and streams tributary to them. Hence long before the mountain chain is finished, the forces of erosion, *i. e.* rain and running water, have been at work lowering the summits as rapidly as they rose. Thus while the Laurentian Mountains, the White Mountains or the Rocky Mountains may never have been higher above the sea-level than now, an enormous amount of sediment has been removed by erosion or *denudation*, as it is often called. Thus over the Appalachian region it is estimated that from 8000 to 20,000 feet of rock have been removed by these slow agencies. From the surface of England not less than from 10,000 to 11,000 feet have been removed. It is estimated that from the Uintah Mountain region, a comparatively limited tract in southern Wyoming, an average thickness of three and a half miles has been removed, the extreme thickness of the rocks composing this group of mountains being nearly five miles.

From these facts it will be seen why geologists demand so great an age for the earth, and why they are disposed to ask for much more time than the astronomers seem willing to allow them. The period of fifteen or twenty million years granted by the astronomers and mathematicians seems too short a time for the building of a world like ours; and it may be that the truth lies between the two extremes.

Our readers having obtained some idea of the materials out of which continents are made, and of the comparatively simple and yet long continued processes by which they have become built up, will now be prepared to understand the successive steps by which our own land has been framed and moulded into a shape fitted for the abode of such a nation as ours, which originally composite and heterogeneous, has become welded into a united and prosperous people. We have coal, iron and petroleum more than enough for ourselves. All the resources of a great republic, the hope of the world, are at our hands. Owing to the inventive genius of our people, distant shores and mountain barriers do not separate us into distinct political sections. They only strengthen our resources and prevent the evils of overcrowding. Our civilization and religion we have brought with us as the best products of the Old World, and it only remains for us to develop ourselves socially and morally as a people under the guiding Power which controls all things material and spiritual, and which has in the past, through the processes of nature which the astronomer, the geologist and naturalist can dimly trace, developed the world, building up continents and mountain chains, and peopling them with successive assemblages of plants and animals, each assemblage improving on the other, until the earth is fitted for the abode of the "lord of creation."

CHAPTER III.

(*Diagram III.*)

AMERICA DURING THE SILURIAN PERIOD.

The earliest chapters in the history of our earth are wrapt in dense obscurity. The means and materials of study, such as the geologist ordinarily uses in unravelling the later chapters, are here wanting. Conjecture and guess-work, in which the geologist no less than the astronomer is obliged to deal, take the place of facts and safe inductions from such facts. Fossiliferous rocks laid down in regular order, the younger upon the older, and containing fossil shells and the hard parts of animals in general, which have withstood the wrecks of the ages and serve as time-marks, all these are wanting in the oldest rocks.

By a study of nebulæ, of meteorites, of comets, of the smaller stars and of other planets than ours, and which are in different stages of development, so to speak, than ours, the ablest mathematicians and astronomers are inclined to believe that our earth has passed through stages of development corresponding to the nebula, the star and the planet. However this may be, and many facts point to such a conclusion, the fossiliferous rocks certainly rest upon older ones, which are stratified and which do not contain any fossils. These rocks, however, being composed of beds of sandstone, pudding stone, (a rock consisting of rounded pebbles mixed with sand,) and of slates and schists, with beds of limestone, and graphite or lead used in making writing pencils, show that they were originally beds of sand, mud and gravel, and were the fragmentary remains of older rocks, of which perhaps no traces survive.

Thus we are led back to times when there was no dry land, when the waters covered the earth, and thence to a period of chaos, a time when the waters of the globe, the elements of the rocks and of the atmosphere formed a chaotic gaseous mass, many times greater in bulk than at present.

But we will not dwell on this theme, referring the reader to the late Professor Pierce's little book "Ideality in Physical Science," for the most modern statement of the views regarding the supposed earliest phases of our earth's history.

The geologist in treating of the earth has borrowed the terms of the historian, and for convenience has divided the earth's age into eras, periods and epochs. These are, as we shall see, more or less arbitrary divisions, since they merge into each other. For example, the Elizabethan Era was succeeded without a break in English history except the death of a monarch, by the Stuart dynasty, and in geological history we shall see that the different periods were signalized by the presence of peculiar assemblages of life, the most characteristic forms dying out at the close of each period to give way to new dynasties.

We have already given on p. 23 the divisions of geological time, and will begin with

The Archæan Era.—Our story will not be a long one, for the history of this era is wrapped in obscurity.

In the northern portions of America there are extensive hilly or mountainous regions formed of granite and stratified granite or gneiss, with great beds of crystalline limestone and iron. The rocks have been carved into shapes of which the most characteristic specimens are the mountains of Labrador. Where the rocks are unstratified and crystalline, like statuary marble only much coarser, they rise into dome-like or sugar-loaf-shaped, conical mountains, which are among the most characteristic of the peculiarly wild and harsh scenic features of the Labrador coast.

The larger part of the mountains of Labrador, however, are colossal mountain-swells, like whale-backs, which rise from a thousand to fifteen hundred feet above the surface of the fiords winding among their bases. These low, broad-based mountains with long straight backs, are the gneiss Laurentian hills, which are best marked along the northern shores of the straits of Belle Isle, and extend eastward towards Quebec.

When after spending two seasons in Labrador we took a walk through the Adirondacks, ascending Mt. Marcy, we were continually interested and surprised to see how different was the scenery of these mountains from the White or Green Mountains. Here were presented to us certain rounded conical bosses, their precipitous sides plunging into deep dark mountain tarns, the exact counterpart of the deeper and smaller Labrador lakes. In later years sailing down the Sogne fiord, after crossing the Fille Fond in Norway, and coasting among the islands skirting the Scandinavian coast, we recognized the same scenic features to which we had become accustomed in Labrador, only the Norwegian Laurentian mountains, rugged conical bosses, are on a far grander, more impressive scale than on the opposite American coast.

These Laurentian rocks in North America form a great V-shaped nucleus. The smaller, broader arm of the V is formed by the Labrador Peninsula, and the larger, slenderer arm extends from Quebec, in a northwest course, forming the northern shores of the Great Lakes and extending towards the Arctic Ocean just west of Hudson's Bay. This V-shaped mass formed the beginning, the nucleus of the North American continent. It was all the dry land then in existence, and the Adirondacks formed an island, lying south of the apex of the V. Other small masses of Laurentian rocks occur south of this V-shaped nucleus, but they may have been carried up during the upheaval of the Alleghany and Rocky Mountains, with the fossiliferous rocks resting on them, and forming a part of the granite nucleus of these mountain chains.

These Archæan rocks are mainly stratified, the strata, some 40,000 feet thick, being much folded and distorted. They must formerly have been the beds of a Laurentian ocean, whose waves washed the base of the pre-Laurentian hills.

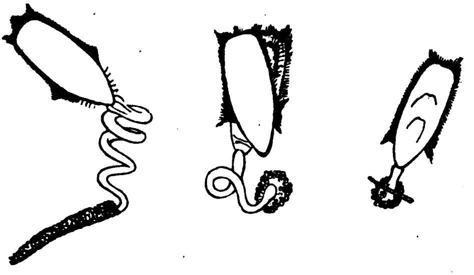
The question naturally arises—was the Laurentian sea inhabited by plants and animals, and if so of what kind were they? Nature has never answered this question. The only indications of life are the beds of limestone, which may have been metamorphosed mud containing corals, shells and other hard parts of animals. The beds of graphite which occur in Canada suggest that this deposit may have been once coal, which is known to be of vegetable origin, and this indicates that there may have been dry land during the Archæan era, with a low vegetation, of which the graphite is the remains. Another fact is the discovery of a small quantity of anthracite coal in northern Norway in rocks of Archæan age. This affords strong circumstantial proof that there was life in some abundance during the Laurentian Age; and it is generally supposed by geologists that there may have been plants and animals in existence, but that owing to the heat and pressure exerted upon them, all traces of life have become extinct. Hence these rocks are called *Eozoic* because they are supposed to have once contained the dawning forms, the earliest types of life. A few geologists, as Dr. Dawson and Dr. Carpenter and others, think that certain appearances in serpentine rocks are really fossils. This fossil is the so-called *Eozoön;* but its nature is regarded as doubtful, while a number of mineralogists claim that it is of mineral origin. Owing to the absence of fossils, these rocks are called *Azoic,* but we will content ourselves with calling the series *Archæan,* as there is no doubt but that they constitute the oldest known system of rocks. Succeeding the Archæan Era was the *Palæozoic Era,* of which the first division was

The Silurian Period.—Our third diagram is designed to represent some of the more characteristic forms, both of those occurring in the oldest fossiliferous strata and those whose remains are found in the uppermost beds.

The rocks of this period are well developed, and were for the first time studied in a portion of Wales, formerly inhabited by the Silures, hence the name Silurian applied to this system of rocks. As these comprise the oldest fossiliferous strata it will be a matter of considerable interest to learn what kinds of beings existed on the lowest and oldest platform of life, this theatre of existence so many ages older than those of Greece and Rome.

Let us first look at the remains found in these oldest strata, called *Primordial* or *Cambrian.* Around the base of the Adirondacks are to be found at Potsdam, in New York, and also on the western shores of Lake Champlain, a set of nearly horizontal beds of hard sandstone, which were formed by the wearing away of the Laurentian hills, of which the present Adirondacks are the remnants. In these rocks and those of this age occuring elsewhere, appear in tolerable abundance, besides a few scattered seaweeds and sponges of very simple form, the shells of several species of *Lingula,* and allied forms called *Brachiopoda,* or armed-footed animals. (Figs. 20, 21.)

The accompanying figure represents the living species which occurs from Chesapeake Bay southward to Florida. It has two flat somewhat triangular valves, and the shell is attached to a long flexible stalk. The Lingula burrows in sand, its stalk becoming surrounded with sand, as seen in the wood-cut, or it is attached to submerged objects. Most Brachiopods live in deep water, attached by their stalk to stones at the bottom of the sea. Our living Lingula has great vitality, and to this may be accounted its wonderful persistency and hold on life from the earliest Silurian times to the present day.



Lingula, a Brachiopod in different attitudes, natural size.—*After Morse, from the American Naturalist.*

Most Brachiopods have solid, ribbed shells. They took the place of ordinary bivalve molluscs (such as the clam and mussel) in the Palæozoic rocks, the latter being far less abundant.

Of about 2000 species of Brachiopods only about 200 species are now living, the remainder having become extinct. As their shells are well preserved, they are among the most useful fossils to determine with certainty the age of the different rock-formations.

Besides these old-fashioned shelled-worms, there were genuine sea-worms closely allied to the Nereids, which are common now-a-days under stones on the sea shore between high and low-water mark. They differed chiefly in the hair-like bristles arranged in bunches along the side of the body, being spiny, like the hairs of young worms of the present day. Worm tracks occur in the Potsdam sandstone, and very clear impressions of the bodies of these Silurian Nereids occur in the primordial or earliest slates at Waterville, Maine.

True molluscs, such as marine snails, were scanty in the Potsdam and equivalent beds; the artist has represented some of a later age on the leaves or fronds of the old-fashioned seaweed in the lower left corner of the diagram (Fig. 2). These snails were like our common gastropods, but belonged to different genera and even to families now extinct.

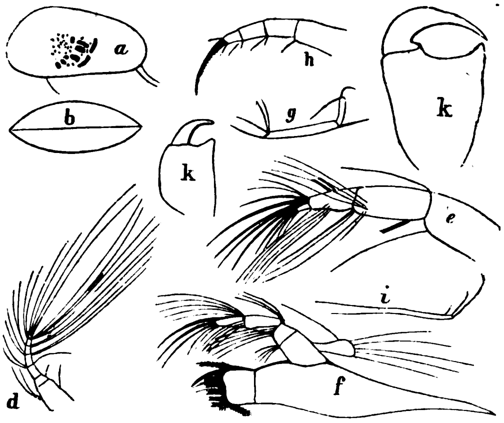
There are also shells of Pteropods, or winged shells (Theca), to be found. A group of these are represented swimming near the top of the water. Judging by the fossil shells, these creatures must have borne a general resemblance to the existing winged snails or molluscs, which for the most part live upon the high seas, in mid-ocean. They are common at the present day all over the ocean out of sight of land, borne hither and thither by ocean currents. They abound at the surface of the Gulf Stream, and when they die their usually light transparent shells slowly sink to the bottom of the ocean. We have collected them off the coast of southern New England, while other species have been observed by us in the floe-ice of the Labrador current, which had passed down out of Baffin's Bay. The colors of the animal are usually very beautiful, and the northern Clione is one of the most exquisite in tints of marine animals.

We see, therefore, that the Pteropods are inhabitants of the sea of every clime and zone of the globe, always living on the high seas. Weak and delicate as are these beautiful creatures with their nearly transparent shells, they belong to a very ancient stock, which has held its own to the present day.

Another type of life, most interesting because it prevailed widely in the Palæozoic seas, was the *Trilobite.* Of these crustaceans upwards of a hundred different species belonging to many genera lived during Primordial times. The largest and most typical was the *Paradoxides* (Fig. 24, Diagram III). Its body was composed of numerous segments, behind a head with large compound eyes. Some specimens in the primordial slates at Braintree, near Boston, are nearly a foot and a half long.

With these trilobites were associated minute shelled crustaceans closely allied to the modern *Cypris* of our seas and fresh-water ponds. This type has likewise persisted with unchanged form to the present day.

But there was another type of crustacean life which began its existence in the Primordial time, which comprised gigantic forms, from six inches to two feet in length, whereas the existing *Nebalia* is only from a quarter to half an inch in length. This type we have called *Phyllocarida,* and Fig. 31 of Diagram III is a



Cypris grandis, from Colorado; *a*, the shell, side view; *b*, from above; *d*, upper, *e*, lower feelers or antennæ; *g*, foot of first pair; *h*, foot of second pair; *k*, claspers. All the figures highly magnified.—*After Chambers, from Hayden's Survey.*

restoration of a Silurian species occurring in the Primordial rocks of Europe.

With these were associated the shells of cuttle-fish like creatures called *Orthoceras*, Fig. 16, (Diagram III.)

We thus see that on the lowest platform of life, the Primordial, there were many highly-developed animals, some like those now abounding in our seas, while most of them belonged to old-fashioned types, which anticipated types of life more highly wrought and specialized in modern times. So highly organized were these primordial animals, that there is a general impression in the minds of geologists, that there must have existed an abundance of life in the underlying Laurentian strata, all traces of which have become totally effaced by the heating, baking and consequent molecular changes which have transformed those ancient beds.

Turning now to the Silurian life as a whole, which our third Diagram is designed to represent, we find it characterized by the general absence, except in the uppermost beds, of any fishes or reptiles. All animals which, like fishes or reptiles, birds, or mammals, have a back-bone and a skull, are called *Vertebrates*, while for convenience all the lower animals are called *Invertebrates.* The Silurian Period was the *Age of Invertebrates.* Shelled worms (Brachiopods), trilobites and large *Orthoceratites* dominated those seas, and only at the close of the period, so far as the geological record states, did fish-like forms appear.

Let us now examine, with the aid of the figures on the third diagram, some of the old Silurian beings. Of plants there were only a few seaweeds, and in the highest beds a few land plants. On the right is a fucoid, like our common rock-weed; in the left lower corner, a large, stout jointed object supposed to be a sea-weed. On its surface are represented some of the characteristic shells of these times.

There was near the close of the Silurian, a low, rank vegetation, in its general features anticipating the flora of the Coal Period. In Ohio and Kentucky remains of a fern, of a tree-like ground pine (the larger tree in the diagram) supposed to be a *Lepidodendron,* while a slender, low growth of *Psilophytons* complete the picture of the scanty vegetation which clothed the slopes of the coast of the Silurian seas.

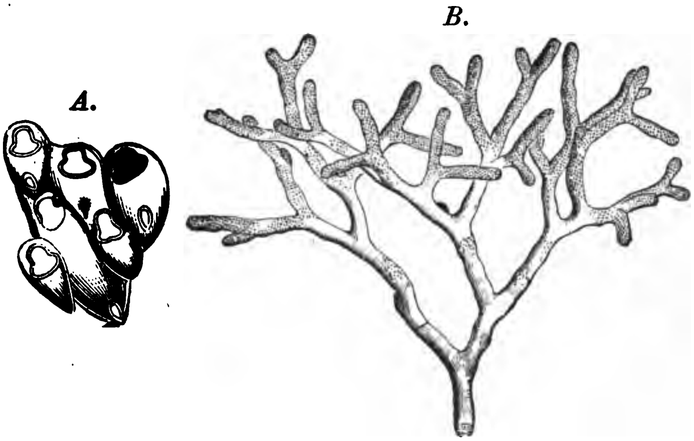
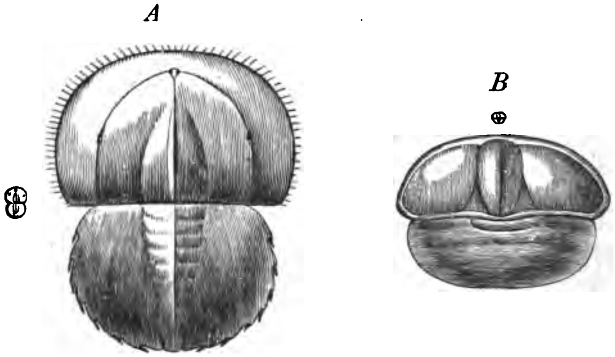


Fig. . Examples of Polyzoa. *A*, cells of the Sea-mat. highly magnified. *B*, coral-like stock of a branching species, natural size. The little dots represent the cell-openings.—*From Packard's "Zoology."*

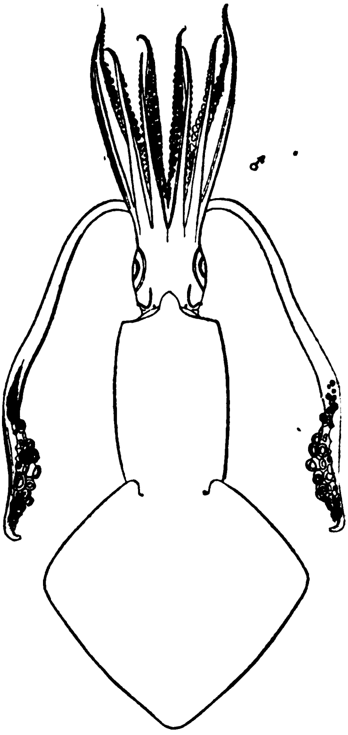
But the marine life was abundant. At Trenton Falls, in New York, and at many other places, the limestone rocks are packed with fossils, as if, says Dana, "laid down in bulk." In almost any hand specimen of the Trenton limestone are to be found the joints of Crinoids, the shells of Trilobites, and of Orthoceratites, together with simple, conical corals, and the coral-like incrustations made by little moss-animals, called Polyzoa (see cut); while in fine-grained shales and slates are preserved the remains of gigantic Crustacea, the forerunners of our horse-shoe crab, and the shields of *Phyllocarida* (Fig. 31) with the minute valves of Cypris-like crustacea.

Let us look more closely at the trilobites. These are represented by Figs. 24-28. At Fig. 25 is a restoration of one of the common species found at Trenton Falls, copied from a restoration by Mr. C. D. Walcott. The animal is drawn life-size. It had many pairs of slender jointed feet, to which gills are supposed to have been attached. Like our horse-shoe crab it probably burrowed in the mud and sand, feeding upon worms and snails. On the top of the head are two large compound eyes, whose structure is identical with that of the eye of the horse-shoe crab. In many respects the trilobite resembled the *Limulus* or horse-shoe crab, especially in the mode of growth. The woodcut represents the young of *Trinucleus*, a trilobite represented by Fig. 28 of the diagram, and when we compare it with the young of the *Limulus*, we see how much alike they were when they hatched from the egg. The trilobite, when fully grown, differs from the horse-shoe crab in having a greater number of segments to the body, and in having gills growing from the front pairs of legs.



A. Young horse-shoe crab, natural size, and highly magnified.
B. Young trilobite, natural size, and highly magnified.
From Packard's Zoölogy.

Another animal very singular and quite unlike its modern representatives, the cuttlefish, was the *Orthoceras*. Fig. 16 of the diagram is a restoration. Its head, arms and front part of the body were somewhat like a common cuttlefish, (see cut) but instead of having the bone inside, the animal appears like the Nautilus to have lived in a chambered shell, so that the *Orthoceras* was perhaps an uncoiled Nautilus. Some of these creatures were six feet in length, as their fossil shells indicate. And they were fierce in disposition, very voracious, and must have played their part as exterminators of the more weak and defenceless creatures about them, and thus been of use to prevent the overcrowding of the sea. One species, *Orthoceras Titan*, "must," says Newberry, "have weighed some tons; and if at all like his congeners of the present day, the cuttle-fish was capable of overcoming any Palæozoic fish."



The Common cuttlefish, ¼ natural size.—*From Report of U. S. Fish Commissioner.*

Fig. 31 represents a restoration of one of the *Phyllocarida*, called *Ceratiocaris.* Nothing is known as to the nature of the feelers and limbs of these large crustacea, so we have drawn those of *Nebalia* the nearest living ally. One species of *Ceratiocaris* attained the length of nearly two feet. They were the precursors of the shrimps and crabs, being more like them than any other Palæozoic crustacea.

But the most formidable crustacea of Silurian times were the huge forms allied to the horse-shoe crab, but in some cases six or seven feet long. Fig. 29 represents *Eurypterus* and Fig. 30 *Pterygotus.* It will be seen that these are simply long and slender-bodied horse-shoe crabs· the head small, but with the same kind of compound eyes; the hinder pair of head-limbs were paddle-like, while as in *Pterygotus,* the first pair ended in great toothed pincers, rendering them formidable antagonists. Unlike the slow, inert, bottom-feeding horse-shoe crabs, these were active swimmers; they dashed about near the surface after small fry, and wherever they went they made their presence felt among their weaker brethren. They must have been active co-laborers with the Orthoceratites in preventing the undue increase of the life about them.

Besides these conspicuous and more typical Silurian forms, there were star-fishes; (Fig. 11) sand-stars, but most common of all the Echinoderms were the stalked star-fishes or crinoids, called sometimes sea-lilies. These were abundant and of different patterns. These forms are represented attached to the mass of coral in the right lower corner. The body of the crinoid was like a star-fish with the rays split up into smaller, rounder branches, and mounted on a stiff, stony jointed stalk, whose joints are often found separate in fossiliferous limestones and are called crinoidal joints. Of sea-urchins, a very few, and these of exceedingly old-fashioned appearance, being round like an apple, and with scattered small spines or prickles, lay here and there scattered over the sea-bottom.

Another extinct type, the *Graptolites* (Figf. 17-19) so named from their resemblance to a pen, lived attached to the rocks at the bottom of the sea. Nothing like them now exist, though their nearest allies are supposed to be the delicate compound moss animals whose colonies, like delicate sea-weeds, are cast ashore on our beaches.

No coral reefs then fringed the shores of the incipient continent, but large scattered masses of *Columnaria* occurred on the ocean bottom, with masses of coral made by hydroid polyps, which probably afforded as now-a-days shelter for myriads of worms and other soft-bodied forms of which no traces now exist. Indeed, just as at the present time, multitudes of marine animals possessed no solid parts or skeletons, so the Silurian seas must have swarmed with forms—connecting links between orders and classes now widely separated—which if the naturalist could have revealed to him, would be a solution of many a knotty problem in Zoölogy.

Very near the close of the Silurian period, when many forms were dying out, their successors lingering on through the Devonian and Carboniferous periods, a new type of life was ushered in, so far as fossil remains tell us, without warning. These were the sharks, and armored fishes called *Ganoids*. They were antiquated, bizarre shapes so outlandish that an ordinary salmon or cod, or even a man-eater shark, would hesitate to recognize them as friends. And yet they were genuine vertebrates; their existence made known to us by their peculiar teeth, and, in the case of the ganoids, by the large solid plates which formed the coat of mail protecting their bodies.

In order to give some idea of the form of the Silurian sharks, we have introduced a modern spiny dogfish (*Spinax*), which is armed with a long spine over two feet in length in front of each dorsal fin. Stout spines like these, from ten inches to nearly two feet long, occur in the Silurian rocks of Europe. Their possessors may have resembled other sharks than the spiny dogfish, and they may have been the precursors of the *Chimæra*, a weird, bizarre, ghost-like ally of the shark.

Besides these spines, pavement-like teeth occurred which resemble the peculiar teeth of the Port Jackson shark now living in Australian seas, and which is the largest figure in the diagram. This is a remnant of the prevailing type of Silurian sharks.

With these teeth and spines, and minute fragments of the rough shagreened skin of sharks, occurred the tail-shields and head-shields of the armored fishes, *Cephalaspis*, *Pterichthys*, and its ally *Pteraspis*. These incoming forms were of diminutive size compared with their Devonian successors. In all, the remains of 40 species have been found in Europe; a small company compared with those which flourished in the Devonian period.

At the close of the Silurian, then, not only had land plants appeared, but also vertebrates; though both forms of life were among the lowest and most generalized in structure of their kind.

The appearance of the American land at the end of the Silurian period has been summed up by Professor Dana in his

Manual of Geology. He shows that over what is now the larger portion of the United States the ocean was comparatively shallow. "In many of the rocks, the ripple-marks of some layers, rill-marks of others, and cracks from sun-drying of others, often in the same stratum, prove the shallowness of the water over great regions, and a wide expanse of exposed beaches and marshes elsewhere. The beds of iron ore in the Clinton group, which have great extent, are other proof of wide-spread marshes over the country, since such deposits cannot form in the open sea. The brines of the Salina period again mark a time of salt marshes or inland salt lakes in New York. The continent still included comparatively little permanent dry land, and that was mainly to the north. It had enlarged somewhat since the Lower Silurian era; but the greater part of the United States was yet to be completed, by the deposition of the Devonian, Carboniferous, and later beds."

As we have seen, life was very abundant, but out of 10,000 species of animals known, all were of types of low grade, such as those we have mentioned; no fishes or other back-boned animals appeared in America, so far as fossils indicate, and only 40 species of fishes, and those the most primitive in form, made their appearance in the European Silurian seas.

After the beds of sand, calcareous mud and beach deposits which formed the bottom and shores of the Silurian seas were by heat and pressure converted into rocks, they were finally, in common with Devonian and carboniferous limestones, upheaved, tilted up, folded over, and their shattered ruins are now found near the summits of our highest ranges of mountains, lying next to the granitic nucleus or axis of lofty mountain chains, or, as in Wales, they form mountains themselves.

We know that the Silurian rocks were the ruins of Laurentian land. In the language of Esquiros, a French geologist quoted by Figuier in his World before the Deluge, "The Silurian mountains, ruins in themselves, contain other ruins. In the bosom of the Longmynd rocks geologists discover conglomerates of rounded stones which bear no resemblance to any rocks now near them. These stones consequently prove the existence of rocks more ancient still; they are fragments of other mountains, of other shores, perhaps even of continents, broken up, destroyed, and crumpled by earlier seas. There is, then, little hope of our discovering the origin of life on the globe, since this page in the genesis of the facts has been torn. For some years geologists loved to rest their eyes, in this long night of ages, upon an ideal limit beyond which plants and animals would begin to appear. Now, this line of demarcation between the rocks which are without vestige of organized beings and those which contain fossils is nearly effaced among the surrounding ruins. On the horizon of the primitive world we see vaguely indicated a series of other worlds which have altogether disappeared; perhaps it is necessary to resign ourselves to the fact that the dawn of life is lost in this silent epoch, when age succeeds age until they are lost in the garb of eternity. The river of life is like the Nile, which, as Bossuet says, hides its head, a figure of speech which time has falsified; but the endless speculations opened up by these and similar considerations led Lyell to say, "Here I am almost prepared to believe in the ancient existence of the Atlantis of Plato."

EXPLANATION OF DIAGRAM III.

Fig. 1. Buthotrephis gracilis. From Dana.
2. Arthrophycus Harlani. From Dana.
3. Archeocyathus Atlanticus, restored.
4. Petraia-coral, restored.
5. Favistella stellata, restored.
6. Columnaria alveolata.
7. Pisocrinus flagellifer. From Zittel.
8. Ichthyocrinus lævis. From Zittel.
9. Homocrinus scoparius. From LeConte.
10. Pleurocystis filitextus. From Dana.
11. Palæaster matutina. From Dana.
12. Orthonota parallela. From Dana.
13. Murchisonia bellicincta, restored.
14. Platyostoma Niagarensis. From Dana.
15. Bellerophon bilobatus. From Dana.

16. Orthoceras vertebrale. After Hall.
17. Monograptus priodon. After Nicholson.
18. Modern Sertularia, to illustrate the general form of Graptolites.
19. Phyllograptus typhus. From Dana.
20. Strophomena radiata. From Dana.
21. Merista levis. From Dana.
22. Theca gregaria, restored.
23. Conularia Trentonensis, restored.
24. Paradoxides Harlani, restored.
25. Calymene senaria, restored. From Walcott.
26. Isotelus gigas. After Hall.
27. " " the same, side view.
28. Trinucleus. After Hall.
29. Eurypterus remipes. From Hall.
30. Pterygotus bilobus. From Woodward.
31. Ceratiocaris, restored.
32. Port Jackson shark, modern. From Dana.
33. Recent shark.
34. Cephalaspis.
35. Pterichthys.

CHAPTER IV.

Diagram IV.

AMERICA DURING THE DEVONIAN PERIOD.

The Devonian is well called the "Age of Fishes." A glance at the diagram will show what strange, bizarre forms, "ancient and fish-like" in appearance, crowded the seas over an area where now the Catskills and Helderberg mountains raise their tops, and over the plains of Ohio and Indiana, now covered by fertile prairie soil.

The remains of the largest, most gigantic armored fish of Devonian times have been found in Delaware county, Ohio. Let us look at the condition of things at the time when the first fishes appeared in American waters. The first remains of fishes, says Professor Newberry in his report on the geology of Ohio, (Vol. I. Palæontology,) are found in the Corniferous limestone, a set of strata lying at the base of the Devonian and immediately over the uppermost Silurian strata. In this oldest Devonian sea, fishes appear in great force, consisting of several genera and species, some of which attained gigantic dimensions.

As we have seen, there was first an Archæan continental mass of land, which was partly submerged, and covered by the Lower Silurian sea, which was rich in the lower forms of life, such as Trilobites, Brachiopods, etc. After standing for hundreds of thousands of years "over what is now North America, the Lower Silurian sea was withdrawn, and was succeeded by a land surface on which no strata were deposited. After the lapse of thousands or millions of years, this land was again submerged as before. In the advance, continuance and retreat of this second submergence, the series of strata we call Upper Silurian were deposited. Of these, the Clinton, Niagara and

Helderberg limestones are made up of organic materials derived from the structures of the animals that inhabited the Upper Silurian sea. In this great calcareous mass we have a record of the marine life of the age, so far as any record has been left of it. As before stated, even here we have in America as yet found no traces of Vertebrates. When, however, the waters retreated to the oceanic basins that have always been sea, and after, perhaps, other millions of years came back again in the Devonian submergence, we find them inhabited by a horde of ichthyic monsters, some of which could hardly have been less formidable than the sanguinary and dreaded sharks of the present day. They were imposing, not only from their size, but from the completeness of their armor, both for attack and defence. Whether any of them had ossified vertebræ or not, remains to be determined; but that a larger part of their structure was composed of true bone than in any fishes of the present period, can be easily shown. The origin and earlier history of this great ichthyic fauna is perhaps written in the unexplored depths of the oceanic basins from which it came; but to us it 'sprang, like Minerva, full-armed from the head of Jove.' With the Devonian sea in its retreat, departed all the group of great bucklered fishes, never more to return." (Newberry).

The largest and most formidable of these mail-clad monsters was the form which occupies a conspicuous position in the diagram (Fig. 1.) The plates and jaw-bones preserved indicate a length of from 10 to 15 feet. It was only exceeded in size by another form whose remains occur in the old Red Sandstone of Europe, the Asterolepis, which is estimated to have been from 20 to 30 feet in length.

Professor Newberry, who described the fish first mentioned, calling it from its great size and formidable appearance, *Dinichthys*, (Greek *deinos*, terrible; *ichthus*, fish) says that this, with other large-sized fishes, lived in an open but shallow sea. "The Huron shale, which contains the gigantic remains of *Dinichthys* and *Aspidichthys*, is also the sediment of an open, though shallower sea; and the fishes which it contains must have inhabited relatively deep water, as we do not find them associated with any traces of shore-lines."

The *Dinichthys* was a very large armored fish allied to *Coccosteus*, but with a shorter, thicker body. The head was very large and the brain-box or skull was composed of thick bony plates, strengthened with internal massive arches, all firmly knit together, forming, as Newberry states, a bony box, not yet found disarticulated, which was at least two feet in length and breadth. These bones on the outer surface were marked with a series of narrow simple furrows "which form an ichthyic arabesque that has no relation to the sutures which unite the cranial plates." The body was protected by plates which formed a shield or carapace, as in *Coccosteus*, *Pterichthys*, (Fig. 2) and the *Asterolepis* of Scotland, so eloquently described by Hugh Miller. One of these plates, the middle one of the back, was fully two feet long, being fully twice as large as in the *Asterolepis*. "No scales," says Prof. Newberry, "have yet been found with the remains of *Dinichthys*; and from their absence we may infer that, as in *Coccosteus*, the posterior portion of the body was covered simply with a tough skin. We are unable to say, from any evidence yet before us, what the form of the body was; whether it was short and massive, as in *Pterichthys* and *Coccosteus*, or more elongated, as in *Asterolepis* and *Heterostius*. We may infer, however, from its affinities, which are closer with *Coccosteus* than with *Asterolepis*, that the body was relatively short and massive. We know that it could not have been less than 2½ to 3 feet in diameter, but it is impossible to say whether the fish was 10 or 15 feet in length, and we do not yet know what were the number and form of the fins."

In order to give some idea of the appearance of this strange fish, we have ventured to adapt for it a restoration of *Coccosteus*, making the head rather larger, the jaws larger, but the body rather shorter, though with the same number and arrangement of the fins. Allowance must then be made for probable errors in what is at least guess-work—the restoration of the form of any extinct animal, unless every bone has been preserved.

This fish was very abundant, as the bones of at least a hundred individuals have been found. It was, judging from its enormous teeth, eminently carnivorous, probably attacking fishes of large size, while it was protected by its heavy colossal plates of armor from the attacks of others of its class. It was, therefore, with the spined sharks, whose remains are found with it, the terror of the Devonian seas.

The largest fish that swam in Scottish and Russian waters was a near ally of the Dinichthys, but which is thought to have been from twenty to thirty feet long. Hugh Miller thus describes this singular creature. "The Asterolepis seems to have been one of at once the earliest and bulkiest of the ganoids. Cranial bucklers of this creature have been found in the flagstones of Caithness large enough to cover the front skull of an elephant, and strong enough to have sent back a musket-bullet as if from a stone wall. The Asterolepis must have at least equalled in size the largest alligators; and there were several points in which it must have resembled that genus of reptiles. Its head was covered with strong osseous plates, ornately fretted by star-like markings, and its body by closely imbricated and delicately-carved osseous scales. But it is chiefly in its ws that we trace a reptilian relationship to the alligators. The alligators among existing reptiles, and the *Lepidostei* among existing reptile-fishes, are remarkable for a peculiar organization of tooth and maxillary [bone], through which certain long teeth in the anterior part of the nether jaw are received into certain scabbard-like hollows in the anterior part of the upper jaw. The hollows receive the teeth when the mouth is shut, as the scabbard receives the sword. Now, in the Asterolepis this reptilian peculiarity was not restricted to a small group of the anterior teeth, but pervaded the entire jaw. Beside each of the creature's reptile teeth, in both jaws, there was a deep pit which received the reptile tooth opposite; and thus, when the animal closed its formidable mouth, the jaws would have been locked together by their long teeth and deep recipient hollows, as the crenellated jaws of a fox-trap lock into each other when we release the spring."

A closely similar form was *Coccosteus*, a fish whose jaws had two sets of teeth, one below the other, while the body behind the head was naked. *Pterichthys Milleri*, (Fig. 2) was a small fish, with two-jointed arm-like appendages attached to the head, while the large plates protecting the front part of the body were studded over with small tubercles. *Pterichthys major* was a larger fish, and was discovered by Hugh Miller. Concerning this fish Agassiz wrote in his great work on fossil fishes: "It is impossible to find anything more eccentric in the whole creation than this genus. The same astonishment which Cuvier felt on examining for the first time the Plesiosauri, I myself experienced when Mr. Hugh Miller, the original discoverer of these fossils, showed me the specimens which he had collected from the old Red Sandstone of Cromarty," and we find Humboldt, says Hugh Miller, referring to this strange Pterichthyan genus in nearly the same terms. These were small; fishes and, with their allies, diminutive compared with those which lived in the outer seas, swam in shoals up the estuaries and into shallow inland waters.

Another type of fish is represented by *Dipterus* (Fig. 3), which had scaly fins in pairs, and with one-sided or even tails, the vertebral column extending centrally to the end of the caudal fin. The modern representative of these fish is the *Polypterus* of the Nile. In the Devonian *Cœlacanthus* the fin-rays were hollow; this genus of fishes persisted in the Carboniferous. (See Diagram V. Fig. 11.)

Associated with these armored fishes were various kinds of sharks, which bore large spines in front of the dorsal fins, and whose teeth were in a general way like those of the Port Jackson shark (represented in Diagram III); their mouths were placed near the end of the head, and were armed with broad, rounded teeth. It is supposed that that strange shark-like fish, the *Chimæra*, dates from Devonian times. This hideous creature differs from the ordinary sharks in having the four gill-openings covered by a sort of membranous flap, while there are but four teeth in the upper and two in the lower jaw. These fishes are the very personification of hideousness, and in the poet's mind they may well be associated with "gorgons dire."

Until within a few years the Chimæra and its allies were supposed to have dated from Jurassic times, but fossil remains have been discovered by Newberry in the lower Devonian rocks of Ohio, indicating a shark closely resembling the living Chimæra. Hence we introduce the figure of a Chimæra as not being out of place in a picture designed to recall the more striking features of Devonian life. (See Fig. 4.)

In the Devonian rocks the teeth and spines of various kinds of sharks have been found. Newberry observes that the teeth of these sharks "present all the varieties of crushing, cutting and piercing organs; and it seems that there was even a greater variety among the sharks of the ancient seas than in those of the present day. It will also be remarked that these old-time sharks were much more generally provided with defensive spines, some of which attained dimensions entirely unparalleled in our present fauna. Another characteristic of this ancient group of cartilaginous fishes is, that their superficial bony organs were generally highly ornamented. The spines to which I have referred are often most elegantly sculptured, and the dermal tubercles are embellished in various ways to a degree rarely observed in living species. Agassiz has shown that a large part of the ancient sharks are zoologically allied to *Cestracion*—the Port Jackson shark—so that this isolated genus, of which there are now but two or three species, may be considered, like the Ganoids and Chimæroids, as a relic of a fauna once immensely developed, but now on the eve of total extinction."

It will be seen from the foregoing pages that the fishes and more especially the old-fashioned Placoderms, or armored fishes, some of them perhaps precursors of our lung fishes, now exceedingly few and far between, were the central figures in Devonian submarine scenes. Upon what did these fishes, when not engaged in eating each other up, or devouring their own fry, subsist? They had, judging by the remains of Devonian shell-fish, trilobites, and the allies of the horse-shoe crabs, a profusion of food swarming in the seas about them, and for whose extinction they may in part be held accountable.

The great "seraphims" or species of *Eurypterus* and *Pterygotus*, so prominent a feature of the Silurian seas, still held their own in undiminished vigor. Our Fig. 5 represents the great *Pterygotus anglicus*, which must have attained a length of six or seven feet, and weighed nearly as much as some of the sharks, or Asterolepis, which probably attacked and devoured them in Scottish seas of Devonian times.

While closely, in all essential points, allied to the common horse-shoe crab, the "seraphim" was much more active and predaceous. It must have swam about near the surface with its long, toothed jaws held widely open in a threatening fashion, an engine of destruction to smaller fish. Its solid crust, its great caudal spine and generally active habits must have made it a formidable competitor of the mail-clad fishes with which it kept company.

Of trilobites, which were not remote allies of the "seraphims," a goodly company lived in the muddy bays and estuaries of the period. Compared with the great numbers which abounded in Silurian waters, there was in the Devonian times a decided falling off. In fact, the trilobite dynasty has now begun to wane; and as a mark of decline, the individuals have lost somewhat of the simplicity of the olden times, and begin to be overloaded with tubercles, spines and other signs of ornamentation. And this tendency to excess of development of the less important, more superficial parts of the body is seen in other groups of the animal kingdom. We have already seen how varied and richly ornamented were the armored fishes, and what diversified shapes the different species assumed. Now, as we shall see, their survivors in the Carboniferous period lost this excess of ornamentation, and became diminutive in size, the type, as a whole, having culminated in the Devonian, and becoming partly extinct in the succeeding period. It was so with the Brachiopods and so with the Ammonites, as we shall see farther on.

This rise, culmination and gradual decay of these dynasties of Paleozoic animals may be compared to the rise, culmination and decay of human dynasties, or to the rise and fall of ancient civilizations, such as the Egyptian, the Assyrian, the Grecian and the Roman. These nations had their periods of simple social customs and simple modes of life. Becoming stronger, more powerful, and dominating over other nations about them, and enriched with the spoils of conquest, they finally enter upon a period of decline, the national type going out of existence as a type, the period of decline being preceded by a time of luxurious living and lack of simple manly strength, so that the nation or empire at last becomes overloaded, or surfeited with wealth, and falls partly by its own weight, and partly by the attacks of its more robust and now more powerful enemies.

Returning to the trilobites, the typical genera were *Dalmanites,* a form which was of large size, but not ornamented with spines. Another genus, however, called *Homalonotus,* had spines on the head, and two rows along the back; but one of the most curious examples was the spiny *Arges,* (Fig. 6, Diagram IV.) which had spines not only on the top and side of the head, but a row along the tail or hinder part of the body. This and other spiny forms thus adopted the prevailing Devonian fashion of wearing long, sabre-like spines; whether for purposes of defence, or for ornamentation, or for both combined, we cannot say.

At this time there came in new groups of crustaceans, one represented by the lobster and shrimps, and the other by the ordinary "pill-bugs" or "sow-bugs" so common in damp places, under sticks and stones, and many allies of which live in the sea. The latter are members of the group of Isopoda. But the Devonian Isopods were, like the armored fishes, gigantic in size, one (*Præarcturus*) discovered in the Old Red Sandstone of Herefordshire, and another, called *Stylonurus*, from Scotland, having been each over a foot long, while few of their living representatives exceed half an inch in length. A genuine fossil shrimp (*Palæopalæmon*) has recently been discovered in the upper Devonian (Erie) shales of Ohio (See Fig. 8, Diagram IV.) It differed mainly in the very large stalk or pedicel of the antennæ, which are much thicker than the legs. So that we have, side by side with the trilobites and "seraphims," which were very old-fashioned forms, representatives of the new-fashioned, modern crustacea so abundant in every tidal pool on the seashore.

Of the Brachiopods, or shelled worms, some new types were introduced, and in some cases these were armed with spines. Such were certain species of *Atrypa, Chonetes,* and *Productus,* (Fig. 12) the latter genus representative of a family more common in the carboniferous rocks, and first appearing in the Devonian ocean.

Curious and very characteristic Devonian Brachiopods, were the winged Spirifers, whose hinge-margin was singularly lengthened out, giving a wing-like aspect to the sides of the shell. (Fig. 11.)

Shell fish, both bivalves and univalves, became more abundant than in the Silurian period, and several forms were like those now characteristic of the West Indian and semi-tropical shores of the Southern States, which indicates the warmth of the sea-water. Of Gastropods, or snail-like molluscs, the Silurian types prevailed, the more characteristic forms being *Murchisonia* and *Bellerophon.*

There were also shells of the Orthoceras. While some were straight, others were partly coiled like a goat's horn. With these were various sorts of *Ammonites* (see Fig. 14) of which we shall have more to say when we come to the Ammonites of the Jurassic formation.

In the shallower parts of the Devonian seas there were extensive coral reefs. The rapids of the Ohio river at Louisville, Ky., are caused by an ancient Devonian coral reef which stretches across the river, a remnant of some ancient submarine reef which may have served as a breakwater to the rollers and billows of the Devonian ocean.

The corals of the Silurian period were either cup-corals, living apart, each individual being planted in the mud probably at the bottom of the sea; or there were more massive forms, as stated in the preceding chapter. But now, especially in the Corniferous epoch, which was, as Dana observes, the reef-building period of paleozoic time, massive corals like those indicated in the diagram (*Phillipastræa,* Fig. 9) and the common *Favosites* (Fig. 10), rose in domes five feet across. Submarine ridges of these corals, with plenty of cup-corals growing among them, some from the falls of the Ohio having a diameter at the top of six or seven inches,—all these, packed together in a luxurious submarine growth, with masses of bud-like crinoids (Fig. 15) among which star-fishes warped themselves along, in their quest for the opening valves of bivalve shells; and to which Brachiopods had anchored themselves, while pearly Nautili crept over the coral polyps, feeding upon these luckless flowers of the sea; all this life congregated about the coral growth has been preserved to us in the fossil coral reefs of the Ohio, of Canada and Northern Vermont.

To complete the picture, trilobites burrowed in the coral sand, or in the deep calcareous ooze of the abysses on the ocean side of the reef. About the outer reefs played the armored fishes, the chimæras, and other sharks of old-time physiognomy, while within the reefs, in quiet, shallow waters, in which strange sea-weeds waved to the incoming tide, there swam schools of smaller, slighter ganoid fishes, whose silvery chased and fretted plates of enamel gleamed in the bright clear waters lit up by the torrid rays of a Devonian sun. For the sky and water were heated ; too hot, possibly too much laden with carbonic acid, for the existence of a high order of terrestrial life.

This brings us to land ; and now let us take a bird's-eye view of the North American land as it may have appeared near the close of the Devonian.

Large additions were made to the Silurian continent, so that an expanse of broad, marshy, low land bordered the Silurian mainland, while low islands, reefs and bars ran out from the low shores. The Laurentian highlands inland were separated by lowlands of Silurian origin, so that small rivers ran down from the hilly interior, and meandering through the plains below, emptied into the sea. There must have been bodies of fresh water, filled by abundant, copious rains, and tenanted by fresh-water mussels, for a species of Devonian Anodonta, or fresh-water mussel, occurs in England. Moreover, a flourishing growth of tree-like ferns and "horse-tails" (see right side of diagram) and giant ground pines or club-mosses clothed the lowlands, while coniferous trees, remotely allied to our yews and firs, clad the hillsides (as seen on the left of the diagram) of the interior of the growing continent.

There is strong evidence that the Hudson river may have begun its existence at this time, for at the close of the period, says Dana, "it may have existed with nearly its present limits." The rivers of New England, or the Connecticut, the Merrimac, Kennebec and Penobscot rivers, may have existed as small streams, while it is thought that the St. Lawrence above Montreal may have sent down to the sea its waters laden with sediments from the Silurian and Archæan highlands, to aid in building up the coast margin of the Devonian continent, silting up the smaller bays and estuaries and depositing the mud and clay, which were rearranged by the tidal currents, and which became tenanted by mud-loving trilobites, worms and Devonian clams.

Dana considers that "nearly all of eastern Canada and New England was probably part of the dry continent, from the close of the Lower Devonian, there being no Upper Devonian or Carboniferous rocks over these regions, excepting in part of Nova Scotia, and near the sea border of Canada, New Brunswick, eastern Maine, and southeastern New England." The Silurian mountains were the present Green Mountains, but this range must have been much lower than at present, and of course less worn and eroded, so that the present shapes of its mountains are probably quite different from those of Devonian days.

We are, however, justified in supposing from the records in the rocks that there was a tolerable abundance of tree ferns, of giant club mosses, and of giant "horse-tail" or equisetum-like plants, which were of the stature of trees. These plants became profusely abundant in the Coal period, and thus the growths of Devonian trees of this sort were the precursors of the thick forests of the Coal Period.

Besides these lowly-organized but colossal forms, allies of those which we trample under foot in walking through the woods or by the banks of ponds and marshes, the remains of coniferous logs, which Dr. Dawson has described under the name of *Prototaxites,* one of which was eighteen inches and the other three feet in diameter, shows that there were probably on the higher and drier parts of the land, forests, though sparse it may be, of the prototypes of our modern yews. But as yet there were no hard-wood trees, and through the Devonian forests no air-breathing vertebrate roamed.

Insect life of primitive forms were, however, not wanting. In pieces of a slate rock in the harbor of St. John, New Brunswick, the late Professor Hartt discovered the scanty remains of a gigantic may-fly and two other net-veined insects, whose wings expanded 3½ inches, together with another insect. It has been claimed by some that these beds were Carboniferous, but with these remains occurred those of a little "seraphim" (*Eurypterus pulicaris*) which type characterizes the Devonian, and were replaced in the Carboniferous by forms like the horse-shoe crab. These fossils occur in the Hamilton shales, with remains of beautiful ferns.

The Devonian may-flies must have had the same habits as those of the present day, and we have represented one fluttering in the air. Like their modern representatives, they must have lived in their earliest larval life in pools and sluggish brooks, surrounded by hosts of other insects upon which they fed. Their gauze-like, gleaming wings could have been seen fluttering through the ferns, and as they hovered over the inlets and lagoons by the low shores, or fell haplessly upon the surface of the water, they must have been snapped up by the small ganoid fish which peopled the quiet sandy and muddy bays. For in the Gaspé sandstones of northern New Brunswick, which are of the same age as the St. John shales, Dr. Dawson has found the remains of small ganoids (*Cephalaspis*, etc.) Under the fallen yew logs, and among the undergrowth of ferns, whose fronds are so abundant and beautifully preserved in the fine shales and sandstones of New Brunswick and adjoining parts of Maine, there must have lived multitudes of insects, both winged and wingless, of which no records have been found.

The great abundance of fossil fish and other animals in the Devonian rocks is supposed to be connected with the deposits of oil in western Canada and Pennsylvania. While coal is known to be of vegetable origin, coal oil is supposed to be largely due to animal life. A similar oil is now made by pressing fish and extracting oil from them. In Scotland deposits of bitumen fill up the crevices in the fish-beds, and most fossil fish are dark, shining as if discolored with the oil of their bodies. While mineral oil occurs in the cavities among Lower Silurian corals, and Upper Silurian limestones are often saturated with oil, and indeed mineral oil is confined to no special formation, yet the oil regions of Pennsylvania and Ohio are underlaid by Devonian shales, and from the "black shale" of these States, and of Michigan, New York and Tennessee, the oil is obtained in greatest quantity. The oil is produced by the heat of distillation, by which it is separated from the rock.

The oil-bearing area in the United States is inexhaustible, some 200,000 square miles being underlaid by rocks more or less oil-bearing.

EXPLANATION OF DIAGRAM IV.

Fig. 1. Dinichthys Hertzeri. Newberry, restored.
2. Pterichthys Milleri. From Dana.
3. Dipterus macrolepidotus. From Dana.
4. Chimæra. From Cuvier.
5. Pterygotus anglicus. From Woodward.
6. Cephalaspis Lyellii. From Dana.
7. Arges armatus. From Dana.
8. Palaeopalæmon Newberryi. From Whitfield, restored.
9. Phillipastræa, reef-building coral. From Dana.
10. Favosites goldfussi. From Dana.
11. Spirifer mucronatus. From Dana.
12. Productus subalatus. From Dana.
13. Platyceras dumosum. From Dana.
14. Goniatites retrorsus. Restored.
15. Nucleocrinus verneuili. From Dana.
16. Modern May-fly. From Packard's "Guide to Study of Insects."

CHAPTER V.

Diagram V.

AMERICA DURING THE CARBONIFEROUS PERIOD.

Soon after the opening of the Carboniferous Period, the eastern coast of the then United States was low and swampy, presenting in an exaggerated way the peculiar features of the peninsula of Florida, or of the lower parts of Louisiana and Mississippi at the present day, with their flat, marshy land penetrated by deep bayous and broad sluggish rivers.

Our fifth diagram is an attempt at a restoration of a scene during the Coal Period, illustrative of the animal and vegetable life.

Let us now wander in the imagination through a forest of the Coal Period, and glance at the nature of the strange, luxuriant, tangled mass of vegetation so dense and rank that the earth, not in those times very stable, fairly groaned under its weight.

The most gigantic form, as well as one of the most abundant, and the most concerned in the formation of coal is the *Sigillaria.* (Fig. 1.) This plant is so named from the seal-like impressions between the longitudinal ribs of the bark, which are the scars left by the fall of the leaves. While the trunk on the lower fourth or third was naked, the upper part of the shaft was clothed with thick overlapping slender leaves. The trees were tall columns, usually not branching, which grew to a height of from 80 to 100 feet, their trunks being sometimes four or five feet in diameter. Their appearance must have been rather stiff and clumsy. They grew in wet, low swampy land, and when overthrown by storms and tornadoes their trunks and stumps must have decayed and turned to mould and peat. Professor Heer, in his "Primæval World of Switzerland," says that the trunks at their base often become quadrangular, and were separated into several thick roots, which subdivided into successive forks, and thus often reached a distance of thirty feet from the stem. "The roots were closely covered with long, cylindrical fibres, which, when detached, left circular protuberances." These roots of the Sigillaria were formerly supposed to have been separate plants, and were called *Stigmaria.* Whole beds of coal are sometimes filled with them; but usually they occur in the layers of fire-clay underlying a bed of coal. As to their botanical relations, the Sigillarias were probably, as Dawson claims, "the Cycads of the Carboniferous Period," but he adds, "they presented among themselves a wide range of organization, on the one hand presenting apparent affinities to Conifers, and on the other to Cryptogamous plants."

Another abundant tree of the coal measures was the more graceful, branched *Lepidodendron* (Fig. 2) or "scaled tree," as its name indicates. Heer describes this tree-like form in the following words. Like the Sigillariæ they possessed a bark of very elegant structure. "They look as if their stems were closely covered with regular scales of a rhomboidal, elliptical, or hexagonal form. These scales must be regarded as leaf-pads, and the little rhomboidal protuberance placed at or above the middle of the scale as the place to which the leaf was attached. From these scars sprang the long, stiff, linear leaves, forming dense tufts on the smaller branches. At the ends of the branches were the fruit-spikes, consisting of numerous shield-like tracts, the stalks of which, standing perpendicularly from the axis, bore the fruits, which enclosed numerous small spores. The stems of the Lepidodendra were repeatedly forked, and they attained to a considerable length and bulk. Stems are known 12 feet in circumference and more than 100 feet in height."

The plant to which the Lepidodendron bore the greatest similarity was the creeping club-moss, or ground-pine (*Lycopodium*) so common in pine woods in a not particularly damp soil. But it should be borne in mind that, as with the animals, these primeval coal-trees were combinations of characters now to be found in separate groups of plants together with other more essential ones peculiar to themselves.

The *Calamites* (Fig. 3), a very common tree-like form, but smaller than those already mentioned, occurs fossil in great abundance between beds of coal. They grew in dense masses like rushes or cane-brakes of to-day, in wet soil or standing water. These plants were on an average from twenty to thirty feet high, and with trunks from eight to ten inches in diameter. The trunk of the *Calamites* was a tall straight shaft, gradually tapering to a point in the sterile forms, but in the fruiting forms ending in a spindle-shaped mass of spore-producing or fruiting organs. Our figure copied from Schimper and Haushofer's restorations gives the general effect of these trees. Their nearest modern representatives are the horse-tail rushes, which grow about a foot high and are familiar to every school-boy, and known to botanists under the name of *Equisetum*.

Associated with these tree-like plants were tree-ferns which clothed the higher, drier parts of the earth with dense forests. Such a tree-fern was the *Pecopteris* (Fig. 4), whose delicate tracery of leaf-work crowned the summit of a slender shaft, rough, however, with the scars left by the falling of the leaves during growth. With these were coarser sorts of tree-ferns (Figs. 9, 10), while there was a dense matted undergrowth of ferns, etc. (Figs. 5, 8), among which grew some short-stemmed broom-like plants, (*Cordaites*, Fig. 6), ending in a branch of long, broad leaves.

A modern feature in coal vegetation are the coniferous trees (Fig. 7) a few species of which grew on the drier hillsides. These conifers are supposed to have been related to the broad-leaved pines which grew in Araucaria in Chili, and others which flourish on Norfolk Island and in Australia. They are to be seen in our greenhouses. Their remains are scanty and obscure and some of them are only known by the microscopic structure of the wood. We have called attention to the most characteristic features of the carboniferous flora. There were in all over 400 species of American coal-plants.

The circumstances under which these plants grew must have been decidedly favorable to the growth of plants of a low order. No hard-wood trees, such as oaks and maples, dropped their leaves on carboniferous soil, nor was the ground carpeted with showy, bright-colored flowers.

Could we wander through an ancient forest of the Coal Period, we should feel emotions akin to those of a modern traveller at his first sight of a New Zealand forest of tree ferns, which probably best represents those of Carboniferous times. We extract the following description of a New Zealand forest situated on the lowlands near the coast, from an article by Mr. I. C. Russell in the "American Naturalist" (Vol XIII, p. 74).

"The traveller who enters for the first time a New Zealand forest, no matter from what land he may have wandered, will find everything new and strange to him. What especially attracts the attention is the great profusion of cryptogamous or flowerless plants, in which these islands are richer than any other country in the world. The ferns alone number about a hundred and twenty species and form the most characteristic feature in the landscape. Thousands of these beautiful plants cover the ground with their low and delicate fronds, as in some portions of our country; others entwine the banks of trees for support; still others attain the size of forest trees and rear their great crowns of feathery fronds to a height of forty or fifty feet in the air, rivalling in their grace and elegance the date-palm of Arabia. As there are but a few birds of song in New Zealand, and a scarcity of insect life, the woods are always silent. This, together with the strange, weird forms of vegetation around, makes a deep impression on the visitor to whom such scenes are new. Despite the luxuriance of the ferns we miss the numerous sweet flowers that in our minds are so closely associated with the deep shade of the forest. In New Zealand the flowers are, for the most part, small and inconspicuous, and lacking in sweetness."

Such was the abundant, luxuriant vegetation of the Coal period. How, then, did coal originate from the carboniferous forests? Before we answer this question let us learn how coal exists in nature.

The rocks in which occur seams and beds of coal are sandstones, very coarse sandstones containing pebbles, called conglomerate, shales and occasionally beds of limestone. These rocks in Nova Scotia are turned up on their edges, as at the Joggins mine in Nova Scotia, and by actual measurement have been found to be 14,570 feet, or over two miles, in thickness. In Pennsylvania the beds of the same are 4000 feet thick. It is estimated that the coal beds themselves are about one-fiftieth of the entire thickness of the formation. A bed of coal is nearly always overlaid by a bed of shale, and underlaid by a thin seam of fine "fire-clay" or "under-clay." In the shale occur impressions of ferns, and leaves and stems of the tree-like coal plants. These may alternate with beds of sandstone, iron or limestone; and these beds of coal with their under-clay and over-shales may succeed one another in some coal fields as many as from fifty to even a hundred times. Beds of coal may vary from a line or two to thirty or forty feet in thickness, but they are seldom more than eight feet thick and are usually less.

Of the different varieties of coal, anthracite or "stone coal" is the hardest, and it burns with little flame. Bituminous coal is softer and burns with a bright yellow flame. Lignite is a still softer coal and abounds in the rocks of the upper Cretaceous and Tertiary age. Another variety is the soft, brown coal of Germany which is so much like ordinary peat that it may be seen that the brown coal or lignite on the one hand and anthracite on the other are extremes of one series, the difference being due to difference in the amount of heat and pressure to which the different kinds of coal have been subjected. The lignite occurs in beds of sand and marl; the anthracite in beds of solid, hard sandstone and conglomerate, rendered so by what is called metamorphism.

It is now generally believed by the best authorities, both in Europe and this country, that beds of coal are simply peat bogs and marshes which have been converted into coal. These peat-mosses or bogs, owing to successive oscillations of the land, have been burried in the mud and sand brought down by the rivers, and then formed land to again subside and to be invaded by the water and again become firm land.

In order, then, to understand how beds of coal were formed, we should study a peat bog or morass. New England is rich in peat bogs, while the Dismal swamp and the morasses of Florida are examples in the Southern states.

By a study of modern peat beds and swamps, the most familiar objects in our rambles, we may explain the formation of coal. All the processes are going on at points along our coast, where by changes of level cypress swamps in the south and sphagnum and pine swamps in the north become invaded by the sea and covered with sand, gravel and mud. Also by experiments in the chemical laboratory the best peat, i. e. that like fine mud, free from bits of wood, may by hydraulic pressure be made into a substance like coal.

It is only within a century, since the invention and application of steam to the mechanical arts, and practically a little over half a century ago that coal has become almost a condition, we may say, of national growth and prosperity. It is only within a period of some twenty years, since 1860, that natural coal-oil has been discovered, brought up by artesian wells and put to practical use. When the whale fishery declined, and the increasing manufactories and all the varied wants of our composite civilization demanded enormous quantities of oil, the vast, incalculable stores of oil which for ages had been pent up in the bowels of the earth, were revealed, and by the energy and inventive genius of our people made at once available.

The oil-bearing rocks of the United States cover a territory some 200,000 square miles in extent, and it is supposed that the supply is practically inexhaustible.

We are equally well off in our supplies of coal. There are estimated to be in the United States 120,000 square miles of workable coal, and our country could supply the world with coal for 200 years to come, while we shall never exhaust the supply necessary for our own wants. The coal product of the world in 1879 was 300,000,000 tons.

Such is the amount of a mineral annually used by the civilized world, which a little over a century ago, before Watt discovered the steam engine, and even at a later date when Robert Fulton ascended the Hudson river in his little steamer, was regarded as a curiosity about which only geologists, who were by the people regarded either as "cranks" or harmless stone-hammerers, busied themselves!

Intimately associated and alternating with coal seams are great beds of iron ore. Nearly all the iron ore worked in Great Britain is taken from her coal mines, and in Pennsylvania, West Virginia, Tennessee, Kentucky and Alabama there are vast deposits of iron ore associated with coal. Hard or anthracite coal was first used in England for making iron in 1836, and two years later it was first used for the same purpose at Mauch Chunk in Pennsylvania. Thus these two great gifts of nature to civilized man—these twin factors in the world's progress—grew up together, so to speak, in the marshy soil and forest-clad land of carboniferous times. The carbonic acid which rendered the air heavy and intolerable to air-breathing, higher animals, so that none could exist in the age of coal; and which also mixed with the iron rust which stained and mingled with the sands and muds of the flats and shores of that age, formed rounded masses—these two substances, the coal and the iron, became the source of the highest comfort and the ministers of the most varied wants of man.

Turning to the animal life of the Coal Period we meet with vertebrate forms which were much superior to the fishes of the Devonian. Animals with limbs and lungs now made their appearance. But many of them never left the water; others crawled up on land, not going far from the water's edge, their tracks being still preserved in the fine sandstone which once formed the muddy shores of some sluggish lagoon shaded by the stiff, strange foliage of calamites and tree ferns overhanging the dark, dank waters.

Our diagram reproduces some of the most characteristic of these amphibious creatures.

The class of modern, living Amphibia is divided into several orders. The lowest are the tailed forms, such as the sirens, the "mud puppy," and the newts or salamanders; and the highest are the frogs and toads, whose young are tadpoles and bear a general resemblance to salamanders. One of the largest of existing Amphibia is the great Japanese salamander which is a yard in length. A creature of nearly equal size is the great siren of southern marshes, which is sometimes a yard long; its body is long and eel-like with external gills; it has no hind legs and very small, weak fore limbs which have three or four toes. Another serpent-like form is the "blind snake" which lives in Central and South America as well as on the West African coast and in the East Indies. They live like earth-worms in the loose, damp soil, feeding on insects. They recall in one point the old fashioned, carboniferous, scaled Amphibia in possessing scales, but they are minute and imbedded in the skin. The young, however, are born in the water and possess external gills.

Such are, then, the modern types of Amphibians. Let us now compare with them the old-fashioned shapes whose slimy, gleaming, snake-like bodies, or huge, bulky, scaled forms, with widely gaping jaws, at times rose above the surface of the lagoon as they snapped at some insect struggling on the top of the water, or pursued some smaller fry of their own kind.

The most characteristic forms of the old-time sloughs and rivers of the Carboniferous period were the *Labyrinthodonts,* a name nearly as ponderous as their own bodies, but which has been coined from the Greek, that tongue so useful to systematists in descriptive science, to express the peculiar nature of the teeth. The teeth of all Amphibians are conical, and so were those of *Labyrinthodonts,* but on making a cross section of the latter they have been found to have a singular structure. The cement of the teeth is infolded in such a complex, labyrinthine way as to suggest the name—labyrinth-toothed.

In their general appearance the Labyrinthodonts were, as Owen says, "something between that of a toad and a land salamander," with the fore feet smaller than the hind ones, capable of walking on land, and covered with scales, but in some cases of enormous size; the head of one species, as indicated by the bones, was three feet long and nearly two feet in breadth, and the body in bulk "rivalled that of the largest crocodiles of the present day" (Owen).

The footprints of a Labyrinthodont found in the new Red Sandstone (Trias), says Owen, resemble "the footprints of a salamander, in having the short outer toe of the hind foot projecting nearly at a right angle to the line of the mid-toe, but are not identical with those of any known Batrachian or other reptile."

The largest Labyrinthodont lived during the Triassic Period, but the earlier Carboniferous forms were the most bulky and imposing of the land Amphibia of the true Coal Period.

One of the aquatic forms was a connecting link between the ganoid fishes and the newts or Tritons. This is the *Archegosaurus,* a restoration of which is given at Fig. 16 of the diagram. Its body was long and slender, its head covered with large bony plates like those of a gar-pike, while the body had beneath ganoid-like scales; it had gills like those of the Proteus, and like that animal, its long tail was finned. Owen further states that instead of feet with toes, the limbs resembled slender, pointed paddles. It was three and a half feet long, and from a scientific point of view was of great interest, serving as a connecting link between the fishes and Amphibia. In this country it was represented by *Trimerorachis* of Cope.

Animals like ordinary salamanders, and not differing in any essential respect, were not uncommon. We have introduced a sketch of *Pelion Lyelli* of Wyman (Fig. 12), which was about a foot long, from data supplied by Professor Wyman's figures, and hints from Professor Cope, the leading American authority on the fossil Batrachians.

Another salamander of the Coal period (*Œstocephalus* of Cope, Fig. 13) was like our southern "Congo snake" (*Amphiuma*) which lives in the swamps near New Orleans and in the bayous of Mississippi. Like the "congo snake," the body of the *Œstocephalus* was long, slender and snake-like, and probably not scaled. The limbs were small and weak, and perhaps only three-toed, like those of the *Amphiuma*. The size of the body was that of a common rattlesnake, but the tail was laterally flattened, as seen in the restoration from a sketch which we owe to Professor Cope.

Another snake-like form (*Ptyonius*) was somewhat like a Siren which lives in southern swamps, but smaller. The head was long and narrow, and the body snake-like in proportions, the tail being long. Only the bones of the hind limbs have been found, and they are weak, but the ribs were well developed. Professor Cope says that "the form of the head is a curious miniature of *Ichthyosaurus*."

But the most decidedly serpent-like in shape was a small creature from three inches to a foot in length, which had no limbs, and whose proportions were like those of the whip-snake. It has been named *Phlegethontia* (Fig. 14) by Professor Cope, who has also described thirty-four species of these Labyrinthodont Amphibia (called *Stegocephala*) from the Coal Measures near Linton, Ohio. The restoration here given is from a sketch by Professor Cope.

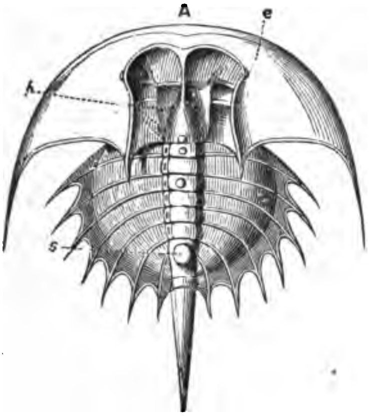
On the right of the diagram, upon the bank, are two scaled amphibious creatures which formerly lived in Nova Scotia. In some points they approached the true reptiles. They had five toes, stout legs and scaly bodies. A rather large animal, called *Dendrepeton,* had short, stout limbs and an elongated tail, and had its skin, and more particularly that of the belly, protected by small bony plates, closely overlapping each other. It may have attained the length of two feet. In the form of the head it was like that of *Baphetes,* which was a more aquatic form. The *Baphetes* is represented with its head out of the water holding a ganoid fish in its mouth (Fig. 17).

Another but smaller land scaly amphibian was *Hylonomus* (Fig. 19), which was slender, and only six or seven inches long. The third form, which is drawn in the act of snapping at an insect, is *Hylerpeton Dawsoni* of Owen (Fig. 18) which Dawson thinks was more aquatic in its habits than the others.

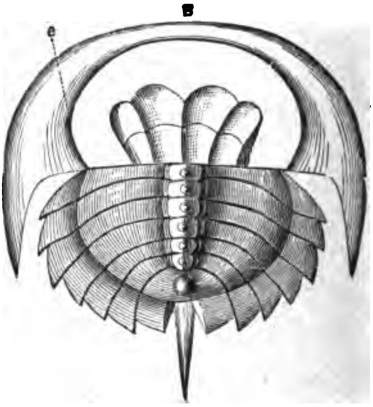
The bones and teeth of these land Amphibians were mostly found in the trunks of *Sigillaria,* and they undoubtedly fed on the galley worms (Figs. 23, 24), and land snails, as well as scorpions and spiders (Fig. 26), which are represented near them. Indeed, insect life in nearly all its most essential types was now abundant. Myriopods of various groups, scorpions and spiders, cockroaches, dragon flies (Fig. 27) and other net-veined insects, and a few beetles are known to have thrived in the coal forests. But none of the highest insects, such as flies, butterflies, ants, wasps, or bees had yet come into existence. A large proportion of the Carboniferous insects were aquatic, living in their early stages in the water, thus affording an abundance of food to the salamanders and other Amphibia which swarmed in the waters.

For the first time also appeared a few air-breathing molluscs, represented by the Pupa (Fig. 21) and Helix, or land-snail, (Fig. 22, both of these figures disproportionately enlarged in the diagram,) which afforded food to the land Amphibians.

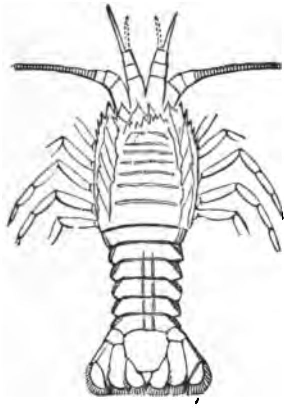
The inhabitants of the deeper parts of the Carboniferous ocean were in general like those of Devonian times. The principal change was the extinction of the trilobites, which were replaced by horse-shoe crabs of small size, and with short tails, like those represented in the adjoining wood-cut. Crabs now first appeared, and several shrimps and Isopods, with old-fashioned sea-urchins. The great ganoids of Devonian seas were succeeded by dwarfed descendants, some of them approximating in form, and thus anticipating the coming, in long ages after, of the bony fishes, like our present herring and cod-fish.



A. Prestwichia, natural size. After Worthen.—*Ill. Geol. Survey.*



B. Euproops, natural size. After Worthen.



A Shrimp of the Carboniferous Period.—*Report of Illinois Geological Survey.*

The close of the Carboniferous Period was a transition epoch, called the *Permian*, when a number of new types were ushered in, and most of the Carboniferous forms went out of existence. New plants, characteristic of the Mesozoic era, such as the broad-leaved pines, *Voltzia,* etc., made their appearance. Among animals, the lung-fish of Australia, called *Ceratodus,* made its appearance, and now for the first time genuine reptiles, like crocodiles, having teeth set in sockets, appeared. They were like the sea-crocodiles of the Trias and Jura, and in some respects allied to the Dinosaurs of the Mesozoic era.

Of these reptiles, one of the best known is a large species from six to eight feet long and named by Professor Cope *Dimetrodon incisivus.* Fig. 20 is from a sketch of the restored creature which we owe to this distinguished palæontologist. It had three pairs of very long teeth like the canines of a tiger, besides smaller conical teeth, while along the back rose a remarkably high crest which extended in much diminished height along the tail.

Meanwhile the Permian water-salamanders had not decreased in size; the large form in the middle (Fig. 15) is the *Eryops megacephalus* from the Permian of Texas, described by Professor Cope, who states that this is the largest Labyrinthodont yet known from this Continent. The sketch was kindly drawn for us by Professor Cope.

With the close of the Carboniferous Period the whole system of beds forming the shallow ocean-bottom were thrown up into a plateau, with the strata folded, and as the result, the Alleghanies, from Canada and the White Mountains to the lofty peaks in North Carolina, appeared as a mountain range, and a large area was added to the Atlantic portion of the continent. Thus after ages of preparation, the Appalachian plateau and mountains rising from it were upraised and completed, and at the opening of the Triassic Period the north-eastern and middle United States were dry land. These great changes in the relative amount of land and water, with the appearance of high mountain ranges, naturally wrought great changes in the life of that time, and accounts for the widespread extinction of most of the Carboniferous plants and animals, especially those living near the shore, or in the adjacent shallow waters. Similar causes account for the introduction of new types of life; while a few possessed of great vitality, or which inhabited great depths in the ocean, persisted in Mesozoic times.

EXPLANATION OF DIAGRAM V.

PLANTS.

Fig. 1. Sigillaria. After Schimper.
2. Lepidodendron. After Schimper.
3. Calamites. After Schimper.
4. Pecopteris. After Heer.
5. Asterophyllites.
6. Cordaites. After Heer.
7. Prototaxites. After Dawson.
8. Neuropteris, a fern.
9. Tree fern. After Heer.
10. Tree fern. After Heer.

ANIMALS.

Fig. 11. Cælacanthus elegans. From Dana.
12. Pelion Lyelli, restored.
13. Œstocephalus. Restored by Cope.
14. Phlegethontia. Restored by Cope.
15. Eryops magacephalus. Restored by Cope. (Permian.)
16. Archægosaurus, restored.
17. Baphetes. After Dawson.
18. Hylerpeton. After Dawson.
19. Hylonomus. After Dawson.
20. Dimetrodon incisivus. (Permian) Restored by Cope.
21. Pupa vetusta. After Dawson.
22. Helix (Conulus) priscus. After Dawson.
23. Xylobius sigillariæ. After Dawson.
24. Julus, restored.
25. Scorpio, restored.
26. Arthrolycosa antiqua, restored.
27. A dragon fly, restored.
28. Miamia Bronsonii, restored.

CHAPTER VI.

Diagram VI.

AMERICA DURING THE TRIASSIC AND JURASSIC PERIODS.

Land and sea during these periods presented more lively and varied scenes than in previous times. The forests were less dense and monotonous, and while the land shook under the tread of herds of colossal reptiles, the seas were haunted by forms which rivalled the fabled sea-serpent of this day in size; and not only the land and sea had their inhabitants, but also birds of the air of unwonted form, and flying reptiles of almost demoniac ugliness flitted between earth and sky. The shores of the eastern United States were then indented by broad, shallow estuaries, now represented by the Connecticut and other large rivers to the southward, which drain the Atlantic seaboard. Our diagram represents the general appearance of life and nature along the shores of the Atlantic, and also the eastern shores of the region which afterwards became the Rocky Mountain plateau, some of the restorations being those of European forms, most of which, however, had representatives in America.

The Triassic Period.—Beginning with the Triassic rocks; these form an interrupted series of beds of mostly bright red sandstones and conglomerates, which extend from the Connecticut valley through New Jersey, Pennsylvania and Virginia into North Carolina. They rest unconformably upon the eroded edges of upturned Carboniferous strata. At Richmond, Va., these rocks contain beds of coal, showing that plant life was there abundant. Similar red rocks occur in New Brunswick and on Prince Edward's Island. Along the eastern flank of the

Rocky Mountains from Montana to New Mexico are also beds of a bright red sandstone, of this age. There as well as along the Atlantic border, these sandstones are remarkably free from fossils.

The most interesting remains are the fossil footprints so abundant at certain localities in the Connecticut Valley. Some of these, the so-called "bird-tracks," were enormous, and were made by colossal reptiles called *Dinosaurs,* which walked on their hind feet, while their forefeet were small and held in the air like those of a kangaroo. Indeed, reptiles were the predominant feature of the Mesozoic era, which is therefore called the "Age of Reptiles."

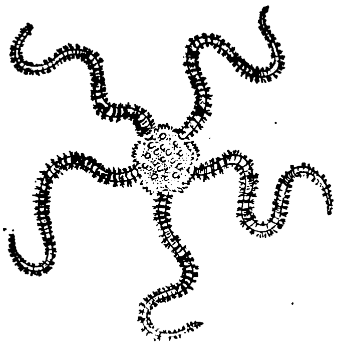
Notwithstanding, then, the absence of fossil bones, reptilian life, judging by the Triassic foootprints, was abundant. These were of two types. The first was a marine crocodile, with, probably, webbed feet adapted for swimming, which is called *Belodon.* (Fig. 9.) It was closely allied to the crocodiles and was their oldest known representative. The Dinosaurs of the Trias were like those of the Jurassic and Cretaceous periods and will be described further on. The Labyrinthodonts were larger and much more abundant than in the Carboniferous, some of them thirty or forty feet long.

Another order of reptiles, whose bones have been mostly taken from Triassic beds in Southern Africa, though some lived in the Permian epoch, were of most singular form. These were called *Theriodonts* ("beast-toothed") by Professor Owen because some of them had a long tooth in each jaw like the canine tooth of the lion or tiger. In fact the group as a whole, called *Theromorpha* by Professor Cope, were very composite in form, the different species combining the characters of the turtles, lizards, the New Zealand Hatteria-lizard, and crocodiles, with those of fossil extinct orders represented by the *Ichthyosaurus* and certain Dinosaurs. Some of the "Beast-tooths" had massive skulls twenty inches long, the jaws in front with the nipping, horny beak of a turtle; while from behind in the upper jaw protruded two long, curved, canine teeth. Another form was still more like the turtles, the jaws being toothless and enclosed in a nipping beak. In certain toothed forms the skull was very short, thick and massive, the jaws armed in front with stout teeth and behind with canine teeth, suggesting in their general style the skull of a lion or tiger, hence the name "beast-tooth."

But the Triassic Period was signalized by the incoming of genuine mammals or hairy quadrupeds. These however were of small size like our opossums. They are supposed by Owen and others to have been allied to the little insect-eating, pouched animal of Australia called *Myrmecobius*, and we have introduced a figure (1) of this animal in the diagram to represent in an approximate way the first mammal which appeared on our continent. It will be observed that is was of a low type compared with those which abounded in the Tertiary Period.

The Jurassic Period. The beds of this period are rich in fossils, so that we can get a tolerably clear idea of the life which existed in great profusion in the earth, in the sea and the air.

The vegetation of the Trias and Jura was made up of pines like the Norfolk Island pine and the Araucarian pines, which now are tall trees, some Norfolk Island pines growing to a height of 100 and 200 feet. Hence the Mesozoic is called the "*Age of Conifers.*" In damp, low grounds, however, grew the Cycas or Sago palm, (see lower left hand corner of the diagram) but no true palms came in until the Cretaceous Period.

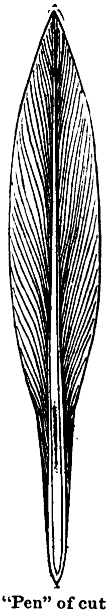


The common snake-star, natural size.—*From Report of U. S. Fish Commissioner.*

The marine animals were of much interest. The diagram shows a submarine scene copied from Heer's restoration of the European coral islands during the Jura. The corals were of the new-fashioned order, and like those forming the modern coral reefs. The oyster and a number of allies appeared during this time, and the ocean shells, both bivalve and univalve, were of the modern forms brought home by sailors from the tropics. The Crinoids were represented by *Pentacrinus*, species of which still exist. The sea-lilies or encrinites are large crinoids, and with them were large sea-urchins, snake-stars like the modern ones and various star-fish.

There were 500 species of Jurassic Ammonites, and they are of great use to the palæontologist as time marks, since certain forms are only found in certain strata.

Very common in the Jurassic seas, especially in the Rocky Mountains, were odd cuttle-fish or squid, whose round pointed cones are in Scotland called "thunderbolts." These conical bodies were situated in the tail of the cuttle-fish, the end of the "pen" or "bone" fitting into them. In a large existing cuttle-fish found by Mr. Dall on the coast of Alaska, a cone was discovered much like that of the Belemnite, so that the nature of this puzzling object has now been discovered. In this recent calamary or cuttle-fish, called *Moroteuthis robusta* by Professor Verrill, the "pen" is "nearly linear with a solid cartilaginous terminal cone." This Jurassic calamary, (*Belemnites densus* fig. 13), whose cones, turned to chalcedony, we have picked up in the Atlantosaurus beds at Como, Wyoming, was like that of this modern species, though somewhat stouter. Cones three inches long and nearly an inch in diameter are abundant, and they belong to calamaries probably about 16 inches long from the end of the body to the origin of the arms; or about the size of an existing common calamary. The squid are very destructive to small fish, darting backwards upon them and biting them in the back of the neck. Fishes played about the coral reefs; and in the Triassic appeared the lung-fish (Fig. 12) which is like an Australian species now living.



"Pen" of cuttle fish.

We now come to the reptiles of the Jura, which were in many cases of colossal size. Besides turtles like our sea-turtle or "loggerhead," and marine crocodiles and gavials, the sea swarmed with saurians as bulky as whales and far more destructive to the life about them.

First in interest is that bepaddled monster, the *Ichthyosaurus* (Fig. 10). It was a fish-like form with a great head, enormous eyes, no neck, yawning jaws with large teeth, while it had paddles like those of whales. The *Ichthyosauri* were from 10 to 40 feet in length ; they were inhabitants of Europe. But one species occurred in the Jurassic of Wyoming. It was apparently toothless and thus differed from the Old World forms.

Abounding in the same seas as the *Ichthyosaurus* were smaller forms, called *Plesiosaurus* (Fig. 11), which also swam by means of paddles, but which had small heads, very long slender flexible necks and a short tail. They must have been swift, active, and have dashed upon their enemies with resistless force.

Still larger forms than these, rivalling the largest whales in size, were certain Dinosaurs of the Rocky Mountain Jurassic. Here may be mentioned the *Iguanodon* (Fig. 7) of Europe, which has been restored by Mantell. Another great reptile, covered with horny scales, was the *Hylæosaurus* (Fig. 6).

Fig. 6 represents one of the colossal saurians of the West, (*Amphicœlias fragillissimus* Cope) which was probably from 80 to 100 feet long. It is represented as floating in the ocean anchored by its heavy tail and legs. An allied form was the *Camarasaurus supremus* Cope (Fig. 5), which was 75 feet long. Its bones show that it, like the preceding, may have either floated near the surface or have walked on the bottom near shore and raised its head out of the water to breathe, as seen in the two figures (No. 5) in the diagram. For these restorations we are indebted to Professor Cope.

The Dinosaurs were more highly developed than any other reptiles except the Pterodactyles. They resembled birds and mammals in having the sacrum composed of four or five consolidated vertebræ ; some of them used their hind-legs in walking, and had a true walk, like mammals, instead of crawling like lizards.

During Triassic times Dinosaurs strode over the flats left by the tide, leaving deep, clearly defined, three or four-toed footprints, which were filled in and covered over by the incoming tide, and thus preserved in the leaves of the great Stone Book.

One small form, the *Compsognathus.* (Fig. 4 of the diagram) was remarkably bird-like, the head being small, the neck long, the hind legs large and long, the fore legs short and small. Numbers of smaller Dinosaurs, some no larger than a cat, and which were flesh-eaters and of light, active habits, abounded in the Jurassic forests of Wyoming and Colorado.

Some of the smaller Pterodactyles were no larger than sparrows and crows, others four or five feet high. The little finger of the fore hand was very long and slender, and to it was attached a broad web like a bat's wing, which connected with the small hind legs. They could thus fly noiselessly and swiftly through the air in pursuit of dragon flies and other insects.

But while the Jurassic Dinosaurs and flying reptiles, called Pterodactyles, closely approach the birds, the latter were not wanting in Jurassic times, and the most surprising form has been discovered in the lithographic slates of Solenhofen, Germany. This is a bird with feathers, and a long tail, with tail-feathers arising in pairs from each of the numerous vertebræ forming a tail rather longer than the body. So reptilian is it in many of its features that one geologist regards it as a bird-like reptile. But Professor Owen and other comparative anatomists regard it as a reptile-like bird. This is the *Archæopteryx*, or "ancient-bird" (Fig. 2).

This outlandish fowl was about the size of a crow, but was more like a hawk in its ferocious habits, for the long bill was armed in each jaw with conical teeth. The head, shoulder-girdle and fore limbs were reptilian in form, the hind legs and claws like those of a hawk. The tail was rather longer than the body, which was covered with feathers. This bird is, then, a connecting link between the reptiles and the birds.

But a genuine bird has recently been found in the Jurassic rocks of the Rocky Mountains by Professor Marsh, who calls it

Laopteryx priscus. This was indeed "the early bird." It was rather larger than the blue heron, which is four feet high, and probably had teeth.

At the close of the Jurassic Period, though we should say more properly, Trias-Jura, for the rocks and life of the two periods cannot well be separated, there were great changes of level and a period of mountain-making on the Pacific coast. For at this date the whole range of the Sierra Nevada, which formed during the Jura a sea-bottom, was upheaved, and the rocks so transformed by pressure and heat as to become slate rocks, with quartz veins cutting across the strata. These are the gold-bearing rocks of California, whose geological age was for a long time unknown, until the fortunate discovery of a Jurassic Ammonite told the story of their age.

The Jurassic was a period of gold-making. During and after the process of metamorphosis of the old Jurassic sea-bottom into slate, fissures and cracks opened. Through these cracks hot steam and vapors with silica or quartz, as well as gold in solution passed, depositing quartz and gold, until the cracks were filled. "Thus the auriferous quartz 'reefs' or veins were made; for the gold and all associated metallic ores were carried in at the same time, the hot waters gathering them far and wide from the slates adjoining" (Dana).

EXPLANATION OF DIAGRAM VI.

Fig. 1. Myrmecobius, an existing Australian marsupial. From LeConte.
2. Archæopteryx. After Owen.
3. Dinosaurs, with footprints.
4. Compsognathus. After Huxley.
5. Camarasaurus supremus. Restored by Cope.
6. Amphicoelias fragillissimus. Restored by Cope.
7. Iguanodon. From Figuier. After Mantell.
8. Hylæosaurus. From Figuier.
9. Belodon. From Figuier.
10. Ichthyosaurus. From Figuier.
11. Plesiosaurus. From Figuier.
12. Ceratodus, lung fish, restored.
13. Belemnites densus, restored.

CHAPTER VII.

Diagram VII.

AMERICA DURING THE CRETACEOUS PERIOD.

The breezy, stirring scene in the diagram before us recalls a bit of the New Jersey coast as it might have looked during the height of the Cretaceous Period. The illustration is copied, with changes in the vegetation, from a drawing by Professor Cope in an article in the "American Naturalist," while the flying lizard (Pteranodon), and birds with teeth are attempts to give an idea of the general appearance of these creatures from Professor Marsh's description of the skeletons.

Great changes were wrought in the vegetable life of this period compared with previous Mesozoic times. Hard-wood trees, such as the oak, beech, hickory, maple, poplar, willow, sycamore, sassafras, tulip-tree and gum tree, with the cinnamon and fig, now appeared, forming rich, dense forests, with scattered red woods (Sequoia) and cypresses, while the stately palm first appeared at this period.

Such a forest now clothes the Southern States, especially about New Orleans, where palm-like trees mingle with the cypress, the live oak, tulip tree and maple. This rich vegetation must have in low ground formed extensive peat beds, as very thick beds of coal or lignite occur in rocks of Cretaceous age in the West.

While there was, then, an entire change in the land plants of the Cretaceous compared with those of former times, the marine life was in all important respects like that of the Jura. And strangely enough, not a bone or tooth, or any signs of a Cretaceous land quadruped has yet been found in any part of the world.

Before we discuss the reptilian life of the Cretaceous, let us first in imagination descend to the ocean depths and obtain some idea of the nature of the life then so profuse upon the sea-bottom.

The surface of the ocean must then, as now, have been rich in floating, surface-inhabiting, minute shells, whose animals were simple minute bits of jelly, but which secreted limestone shells, called *Foraminifera*, many of which were miniatures of the Nautilus shell. When the animals died the shells sank to the bottom, forming an ooze. This deep-sea ooze, made up of these shells mixed with spicules, or the hard parts of sponges, with spines of sea-urchins, etc., in the European seas of the time, formed a mass of white calcareous ooze, which upon becoming consolidated and upheaved, formed the chalk cliffs of the English channel. If a piece of native chalk—not the prepared chalk crayons now in use—be pulverized and placed under the microscope, the shells and other objects will be seen. It is this chalk-like ooze which is now forming in the quiet ocean depths beyond the reach of tides and waves and ocean currents.

But along the coast of New Jersey during our Chalk Period the ooze and the delicate shells composed of numerous cells were subjected to different conditions, and formed the "green marl" so valuable as a fertilizer. "After their death the chambers of the cells became filled with the fine mud formed of dissolved clay, oxide of iron and other substances, which are enumerated by Prof. G. H. Cook, in his valuable report on the Geology of New Jersey. When the beds were raised, the drying, and other agencies brought to bear, decomposed the delicate shells, and left only the hardened mud as casts of their chambers. Hence the green marl now resembles gunpowder, deriving its peculiar color from the protoxide of iron." (Cope in "American Naturalist," Vol. 1). From this marl the remains of the great reptiles represented in our diagrams were dug. It is interesting to know that similar green sand is now in process of formation off the present coast of New Jersey.

Scattered through the marl are the shells of oysters and the like, (Figs. 3, 4, 5) with other shells, (Figs. 6, 7) sea urchins, (Figs. 1, 2 of the diagram), Brachiopod shells and belemnites, as well as corals.

Now the Ammonite type began to wane, and at the close of the Period went out with a great display of curious, bizarre shapes. While some retained the old-fashioned ammonite form, in others the shells began to uncoil, as in the boat-shell, *Scaphites* (Fig. 8) ; another form became twisted as it uncoiled, as in *Turrulites* (Fig. 9), until finally in the staff-shell, *Baculites* (Fig. 10), the shell became straight and flattened.

At this time true bony fishes, like the herring and smelt, were introduced. Such was the *Osmeroides* in the diagram, and *Portheus* of Western Cretaceous deposits.

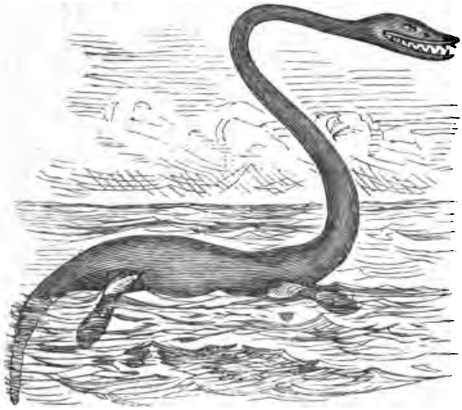
Large land reptiles still abounded, as in the Trias-Jura. That resting its fore feet on the maple tree was a great vegetable-feeding reptile called *Hadrosaurus*. It was about 25 feet in length. Its head was more blunt than represented in the diagram, and the teeth were small and flat, and could not have been seen when the mouth was partly open.

The large land reptiles which browsed upon trees and underbrush were kept under by carnivorous forms of the same order. One of the best known is the great creature standing on the rocky shore in the foreground, which has been described by Professor Cope in the first volume of the "American Naturalist" under the name of *Lælaps*. It stood eighteen feet in height.

But the sea-monsters of this Period were striking from their size and their puzzling affinities. Professor Cope thus describes in the "American Naturalist" the *Mosasaurus*, whose bones are frequently met with in the Cretaceous deposits of New Jersey and the Far West; and also the *Cimoliasaurus*, the Plesiosaur-like form in the foreground, whose tail, however, is probably drawn too long.

"The *Mosasaurus* was a long, slender reptile, with a pair of powerful paddles in front, a moderately long neck and flat, pointed head. The very long tail was flat and deep, like that of a great eel, forming a powerful propeller. The arches of the vertebral column interlocked more extensively than in other reptiles except the snakes, presenting in a prolongation of the front of one, which enters beneath that immediately in advance of it, a rudiment of that extra articulation called the 'zygosphenal.' In the related genus Clidastes, this structure is as fully developed as in the serpents, so that we can picture to ourselves its well-known consequences; their rapid progress through the water by lateral undulations; their lithe motions on land; the rapid stroke; the ready coil; or the elevation of the head and vertebral column, literally a living pillar towering above waves or brush of the shore swamps. While the construction of the skull was as light as that of the serpents, it was, apparently, not so strong. The sutures are more frequently of the squamosal type, and the brain case was not as fully ossified in front. The teeth, too, are less acute, and therefore less adapted for retaining struggling prey. While the jaws were longer, the gape was not so extensive as in serpents of the higher groups, the os quadratum, the suspensor of the lower jaw, though equally movable and fastened to widely-spread supports, was much shorter than in them. But there was a remarkable arrangement to obviate any inconvenience arising from these points. While the branches of the under jaw had no sutural connection, and possessed independent motion, as in all serpents, they had the additional peculiarity, not known elsewhere among vertebrates (except in a few snakes), of a movable articulation a little behind the middle of each. Its direction being oblique, the flexure was outwards and a little downwards, greatly expanding the width of the space between them, and allowing their tips to close a little. A loose, flexible, pouch-like throat would then receive the entire prey, *swallowed between the branches* of the jaw; the necessity of holding it long in the teeth, or of passing it between the short quadrate bones would not exist. Of course the glottis and tongue would be forwards. The physiognomy of the reptile, with apparently dislocated jaws and swollen throat, as he passed a Chimæra to his internal laboratory, could scarcely be prepossessing."

Another Plesiosaur-like form was the *Elasmosaurus,* a restoration of which by Professor Cope is given in the accompanying wood-cut. *Elasmosaurus platyurus,* from Kansas, was probably the longest species, measuring perhaps 50 feet, the neck being 22 feet long. "This creature was carnivorous, and could, no doubt, like the snake-bird, swim at a considerable distance below the surface of the water, and reach to the surface for air, or explore the depths or plunge for fishes to the depth of forty feet."


Elasmosaurus. Restored by Cope.

The turtle seen swimming on the left was like a snapping turtle, and was about six feet in length; it was supposed to have been marine in its habits, and to have lived on crushed shells for food.

The gavials or narrow-nosed crocodiles of the Cretaceous Period were numerous. One of these (*Thoracosaurus*) is seen crawling up the bank with a fish in its mouth, and another allied form is disputing his progress under cover of the undergrowth of the forest.

The Pterodactyles of the Western Cretaceous deposits were nearly all toothless, but were much larger than any whose remains are found in the Old World. One of these toothless forms described by Prof. Marsh was enormous, its wings spreading twenty-two feet. Such a winged lizard our artist has represented as flying through the air.

The bird life of the period is extremely interesting. We are indebted to Professor Marsh for our knowledge of most of the fossil birds of this country.

The largest and most interesting bird was the *Hesperornis* of Western Kansas. This bird was a diver, nearly six feet in length, with a long neck, the long jaws armed with teeth, and the tail bones very long, while the wings were nearly wanting, being very small and useless in flight. It is represented as swimming in the water on the extreme right of the diagram.

Another bird with teeth was the *Ichthyornis*. This was about the size of a pigeon; it had large wings, and bore a general resemblance to a gull, except that the long jaws were provided with teeth. In the diagram it is represented as sailing in the air on the extreme right.

Cormorants also lived as early as the Cretaceous. One is drawn flying in the air under the Pteranodon, or flying lizard, while two are fishing on shore near the diver. The remains of two cormorants from New Jersey and of a third species from the Cretaceous deposits of Western Kansas have been described by Professor Marsh. Another bird (*Laornis*), nearly as large as a swan, also lived in New Jersey during Cretaceous times. As yet no remains of land birds, such as the singing birds, have been described, and it is unknown whether the Cretaceous forests were enlivened by singing birds or not. The record as to Cretaceous mammalian life is a blank.

EXPLANATION OF DIAGRAM VII.

Fig. 1. Echinus (Goniopygus) From LeConte.
2. Echinus (Galerites). From LeConte.
3. Ostrea. From LeConte.
4. Inoceramus. From LeConte.
5. Exogyra? From LeConte.
6. Cypræa. From LeConte.
7. Aporrhais. From LeConte.
8. Scaphites. From LeConte.
9. Helioceras. From LeConte.
10. Baculites. From LeConte.

CHAPTER VIII.

Diagram VIII.

AMERICA DURING THE TERTIARY PERIOD.

Connecting the Cretaceous and Tertiary Periods was a transition epoch called the Laramie or Post-Cretaceous, when the reptilian life of the Cretaceous abounded along the shores of land covered by a growth of Tertiary plants. During this time the lignite or soft coal of Colorado and Wyoming was deposited.

At the beginning of the Tertiary, the present outlines of the North American continent were assumed. The Rocky Mountains had nearly their present shape, and the Sierra Nevada range formed the western coast-line, (the Coast Range not being elevated until the late Tertiary), and the western portion of the continent was added to the eastern, forming one great continental mass. As the western part of the continent rose, the sea drained off, leaving in the great central area between the Rocky Mountains and the Sierra Nevada masses of brackish and fresh water. The lake basins of the early Tertiary (called *Eocene*) were filled with a great body of mostly fresh water which extended from the head-waters of the Yellowstone river to New Mexico and Arizona, and were bounded on the west by the Wahsatch mountains.

While lower Tertiary deposits rich in marine fossils occur near the shore of the Gulf of Mexico, the chief interest centres about the Tertiary beds of the central United States as above defined; for the shores of the great Wahsatch lake were populous with mammals of several hundred species, many of them vegetable-feeders, with carnivorous types to keep the former within due limits.

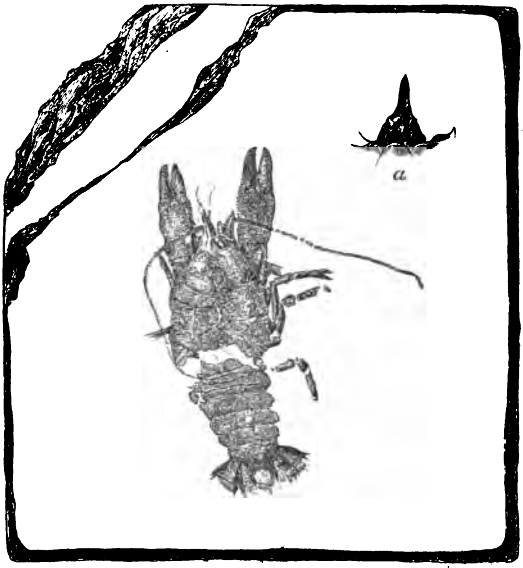
Our eighth diagram contains figures of some of the animals most characteristic of the early Eocene times in North America. The most conspicuous and largest of the early Eocene mammals was the *Coryphodon* (Fig. 5, this and Fig. 8 from a restoration received from Prof. Cope), a generalized type, with features anticipating the tapirs and bears. With them was associated the *Phenacodon* (Fig. 8), which, like the Coryphodon, was a precursor of the hoofed mammals (Ungulates) such as the pig and ox, while the *Eohippus* of Marsh was the beginning of a series of over twenty kinds of horse-like forms which lead up to the modern horse.

As time wore on, the Wahsatch lake contracted into two smaller bodies of water, the middle Eocene or Bridger lakes. And now mammalian life became much more abundant and certain species were colossal. Such was the *Loxolophodon* of Cope. Fig. 6 is a conjectural restoration of this animal, kindly prepared for us by Dr. H. F. Osborn, of Princeton. This creature was of elephantine proportions, armed with tusks and vicious-looking knobs on the head. From snout to rump the animal measured fully twelve feet; it stood about six and a half feet high at the withers and very little lower at the rump; the legs were shorter than those of the elephant, but longer than those of the rhinoceros (Osborn).

Besides this and allied forms, there were *Tillodonts,* animals which combined the head of a bear with the incisors of rodents and the general appearance of hoofed animals. An example of the Creodonts, which were flesh-eaters, is *Mesonyx ossifragus* Cope. A lemur-like form ten inches long, with a thumb on each foot, was *Anaptomorphus homunculus,* (Fig. 19, from a restoration furnished by Prof. Cope).

Other Eocene mammals were generalized types anticipating the cat, wolf, fox, bats, squirrels and moles, as well as the *Eohippus,* which preceded the horse-like forms.

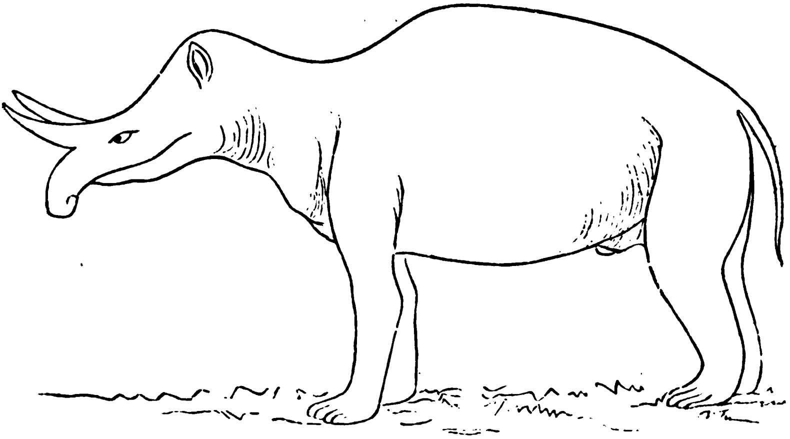
In the early Tertiary, also, ostrich-like forms, but nearly twice as large, *Diatryma* Cope (Fig. 1), existed in Texas. It had shorter legs than the ostrich. Wading birds and eagles, (Fig. 2) as well as snakes, also appeared in the early Tertiary.



Lower Tertiary Cray-fish.—*From Hayden's Survey.*

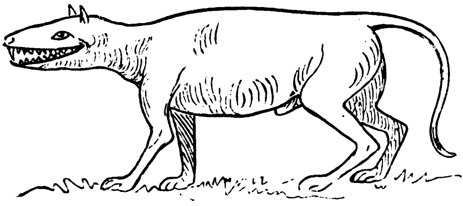
In the brackish and fresh waters herring-like fishes and even skates appeared, and in the fresh waters a species of cray-fish (*Cambarus primævus* Packard).

The middle Tertiary, or Miocene, was also rich in mammalian life. The White river formation is composed of the sediments of extensive lakes extending from near the Missouri river to eastern Wyoming and Colorado. This great lake basin was caused by a subsidence of the region just named. Similar bodies of fresh water occupied a large part of what is now Central Oregon and certain areas in Northwestern Nevada. According to Cope, the most characteristic mammals of these regions were snakes, primitive camels (*Poëbrotherium* Fig. 16), and "ruminatings hogs" (*Oreodon* Fig. 9), as Leidy has called them. With these occurred the bones of another hog-like form, called *Elotherium*, and with them were associated the strangest beasts of all, which were nearly as large as elephants, but with shorter limbs, and feet like those of the rhinoceros, with four toes in front, and three behind; while the head was large and very long, as in the rhinoceros, and armed with a pair of stout diverging bony protuberances on the anterior part of the maxillary bones in front of the orbits, as in *Symborodon acer* of Cope;* such were the species of *Symborodon* (Figs. 7, 8), *Brontotherium* and *Menodus.*



Symborodon acer. Restored by Cope.

The carnivorous animals of the White River beds included species of *Hyænodon,* which had dog-like characters, with three true molars shaped like the cutting or sectorial teeth of a cat or hyæna.



Hyænodon horridus. Restored by Cope.

Another Miocene form was a rhinoceros-like creature, but with the horns placed transversely across the mouth. This was the *Diceratherium,* of which Fig. 13 is a conjectural restoration. The flesh-eaters of this time were primitive cats, dogs, tigers and panthers, of which *Hyænodon* was a typical form. In Europe flourished an elephantine form called the *Dinotherium.*

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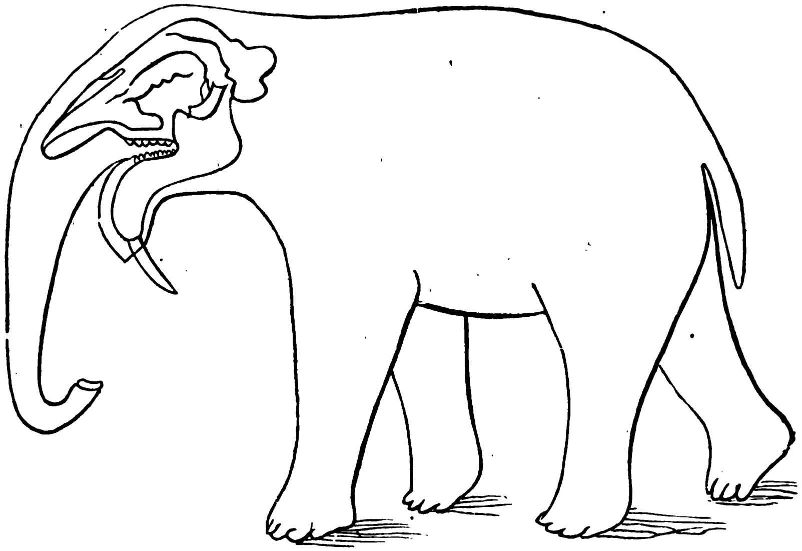
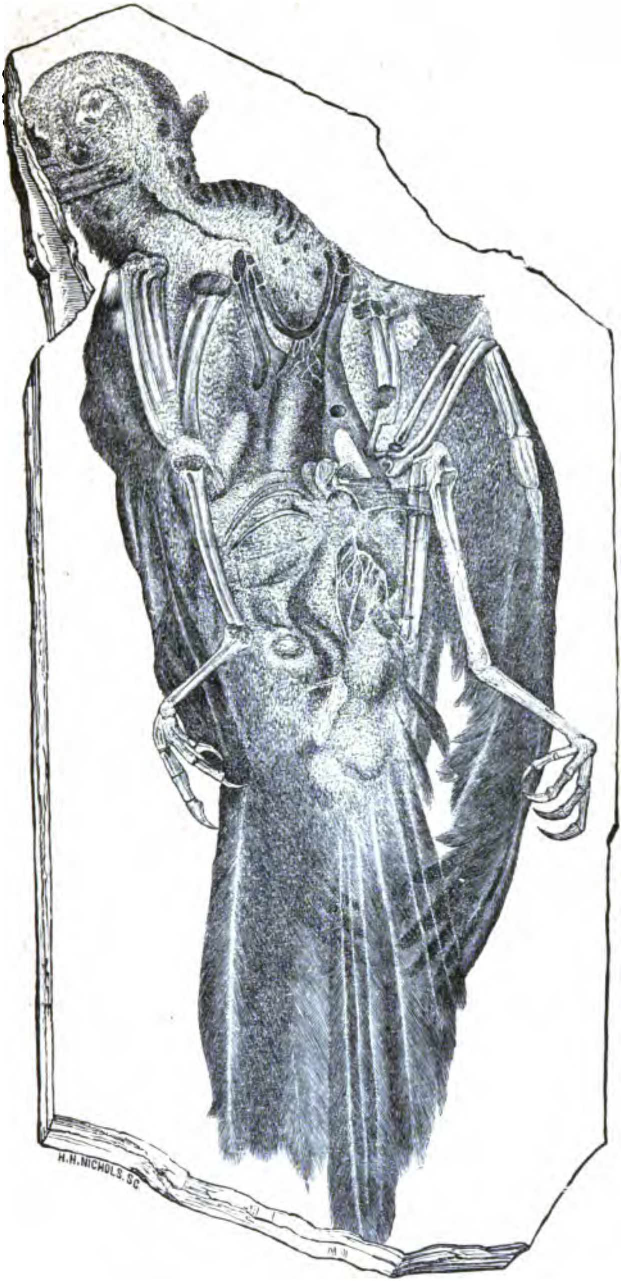
* In the accompanying cut the feet are not correctly engraved.

The now famous insect beds of Colorado and the Green river beds of Wyoming have disclosed, according to Mr. S. H. Scudder, upwards of 2,000 species of spiders, dragon flies, grasshoppers, bugs, beetles, flies, butterflies and ants; and also a bird, allied to our cedar bird and pewees. It was described by Mr. J. A. Allen in the Bulletin of Hayden's U. S. Geological Survey of the Territories as *Palæospiza bella.*

The third and last division of the Tertiary was the Pliocene. Of this epoch the Loup Fork beds are the most extensive deposits, their distribution indicating that the fresh-water lakes covered a wider extent of continent than those of any other period in American geological history. Fossils from these Loup Fork beds have been found at numerous localities "between the Sierra Nevada and the Rocky Mountains, from Oregon to New Mexico, and over parts of the Great Plains of Colorado, Kansas, Nebraska and northward, and in the valleys of the Rocky Mountains. King has shown that the beds of



Brandt's Restoration of the European Dinotherium.—*From Packard's Zoology.*



Fossil Tertiary Bird, Colorado.—*From Hayden's Survey.*

this epoch are slightly elevated to the westward, thus proving that the elevation of the Rocky Mountains had not entirely ceased at that late day."[*]

The characteristic Loup Fork mammals were hornless rhinoceroses, elephants, mastodons, lama-like forms (Fig. 17), camel-like creatures (Fig. 18), three-toed horses (*Hipparion* or *Protohippus*, Fig. 20), deer (Fig. 19), long-chinned Mastodons (Fig. 14), peccary-like creatures (Fig. 12), tapirs (Fig. 11), bisons (Fig. 15); while primitive monkey-like forms (Fig. 24[†]), squirrels (Fig. 4), beavers and opossums (Fig. 3), lived in the Pliocene forests. The plant-eaters were prevented from multiplying too rapidly by the sabre-toothed tiger (*Machairodus* Fig. 22), and smaller cats and dogs.

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[*] See an article in the *American Naturalist* for March, 1882, by E. D. Cope, which gives the latest summary of our knowledge of American Western Tertiary Geology.

[†] The figure is that of a South American monkey, and similar forms occur fossil in Brazil. The nearest approach to a monkey in the North American Miocene beds of Nebraska was *Laopithecus*, according to Marsh.

EXPLANATION OF DIAGRAM VIII.

Fig. 1. Diatryma gigantea Cope, restored conjecturally.
2. Eagle.
3. Opossum.
4. Squirrel.
5. Coryphodon, front and side, restored by Cope.
6. Loxolophodon, restored by H. F. Osborn.
7. Symborodon bucco, restored by Cope.
8. Symborodon trigonoceras, restored by Cope.
9. Oreodon Culbertsoni, restored by Cope.
10. Phenacodus, restored by Cope.
11. Tapir.
12. Peccary (Dicotyles).
13. Diceratherium, restored.
14. Mastodon.
15. Bison.
16. Poëbrotherium Wilsoni, restored by Cope.
17. Lama (Auchenia), restored.
18. Camel (Procamelus), restored conjecturally.
19. Deer.
20. Hipparion, restored. From Zittel.
21. Hoptophoneus primævus, restored by Cope.
22. Machairodus, restored. From Waterhouse Hawkins.
23. Anaptomorphus homunculus, restored by Cope.
24. Monkey-like form, to illustrate, conjecturally, Laopithecus.

CHAPTER IX.

Diagram IX.

NORTH-EASTERN AMERICA IMMEDIATELY BEFORE THE GLACIAL PERIOD.

Between the genuine Tertiary and the Quaternary Periods there was a transitional epoch, called by different writers, late Pliocene, Post-Tertiary, and by others regarded as the opening epoch of the Quaternary. In the Far West and on the Pacific coast the beds of sand, etc., the sediments of extensive lakes, contain the remains of horses, lamas, camels, mastodons, the rhinoceros, mylodon, mammoth, and two species of horse. In these beds, called the *Equus* beds, as they contain the remains of the modern type of horse, it is claimed that human bones and implements have been found.

In the Eastern Atlantic States, especially Virginia and Pennsylvania, the bones of numerous quadrupeds have been found and described mostly by Professors Leidy and Cope. Our diagram is designed to illustrate the assemblage of animals which peopled the Atlantic Middle States immediately before the Glacial or Ice epoch. This comparatively rich and varied fauna and flora were swept out of existence in the Northern States, at least, by the advent of the Ice period, though in the Southern States they may have lingered through the Glacial period.

It is interesting to observe some of the characteristic animals of this time, whose remains are found in caves in Pennsylvania and Virginia, and in fresh-water beds of sand and silt in the Southern States, which are of post-glacial age. Foremost in interest was the *Megatherium* (Fig. 1), a colossal sloth eighteen feet in length, which could walk on the ground. It uprooted and pulled down large forest trees, browsing upon the branches and leaves. With it were associated sloths, other giants, the *Megalonyx*, and the *Mylodon* (Fig. 2), which was the size of a buffalo, and also a creature (*Castoroides*, Fig. 3), by some regarded as a large beaver, but by Mr. J. A. Allen considered to have affinities with the Chinchilla, and by Wyman to be related to the Capybara, or water pig. It was of the size of the black bear. Tapirs and peccaries, which are now restricted to Central and South America, were prominent forms, and with them were associated animals now inhabiting eastern America, as the woodchuck, squirrel, mice, porcupine, hare, mole, raccoon, wolf, weasel, sabre-tooth tiger, horse, deer and a large bison (*Bos latifrons*).

To show at what a rate geological extinction in the mammalian life of our continent went on, it may be remarked that at present there are but about 300 species of mammals, where probably not less than a thousand species existed during the entire Tertiary Period in the United States.

EXPLANATION OF DIAGRAM IX.

Fig. 1. Megatherium, restored. From Figuier.
2. Mylodon, restored. From Figuier.
3. Capybara, or water pig of South America, to illustrate the probable general appearance of the *Castoroides*.
4. Tapir.
5. Peccary.
6. Bison.
7. Moose.
8. Reindeer.
9. Virginian deer.
10. Musk sheep.
11. Cave bear, near the Grizzly Bear.
12. Beaver.
13. Mammoth (Elephas Americanus). (Drawn disproportionately small).
14. Mastodon.
15. Porcupine.
16. Cougar or panther.
17. Squirrel.
18. Horse.
19. Musk rat.

CHAPTER X.

Diagram X.

NORTH AMERICA DURING THE GLACIAL PERIOD.

The Tertiary Period was brought to a close by great changes in the climate of the northern hemisphere, and as the result, the northern part of our continent was clad with ice, during both winter and summer. Our tenth diagram is designed to give an approximate idea of a landscape in New England at the height of the Ice age.

At the opening of the Glacial period the northern portion of the continent stood at an elevation of from 500 to 1000 feet higher than at present, and probably the mean annual temperature of the northern United States was thirty degrees (Fahrenheit) lower than at present. We have already (pp. 8-14) described the nature of glaciers, and their former distribution in North America. The Quaternary or Glacial Period in Northeastern America may for convenience be divided into four epochs, viz :

1. The Glacial Epoch.
2. The Marine, or Leda Clays (Champlain Epoch of Dana).
3. The Sea-Beach Epoch.
4. The River-Terrace Epoch.

It should be borne in mind, however, that these epochs are quite artificial, for they overlapped each other.

During the 1st or Glacial epoch the present river valleys and the larger part of the land were covered with ice, the glaciers moving into the sea carrying or pushing before them the ground moraines, which form, perhaps, the banks and shoals now existing along our coast from Newfoundland to New Jersey. Here, then, existed the scenic features and life now confined to the Arctic regions. The present aspect of Greenland and of Spitzbergen may serve as illustrations of the appearance of the land, the sea, and life during the height of the Ice age.

At the incoming of the 2d epoch there began a change of level of the land, the climate grew milder, the ice began to melt and the snow-line receded from the coast, the glaciers gradually melting away, until finally they retreated to the interior, filling the valleys of the White, the Green and the Adirondack Mountains, and the highlands of New England and British America. The land in the northeastern part of the continent meanwhile sank much lower than its present level, and of course much below the level of the continent during the height of the 1st or Glacial epoch.

Thus the sea covered a large proportion of the lowlands of New England and Canada, for beds of clay—our finely stratified brick-yard clays—were then deposited. The materials comprising them were assorted and arranged by the waves and tidal currents of the Quaternary sea, which at the close of the 2d epoch laved the feet of the mountains of the interior at points varying perhaps from fifty to a hundred miles from the present coast. The moraines inland were only partly stratified, the beds of clay and sand resting on the original, unstratified, morainal mass.

The evidence that the sea formerly stood over the coast is the presence of marine shells of species like those now living either off shore or in the Arctic ocean, in beds of clay twenty or thirty miles from the present shore, or near shore in Maine, 217 feet above the present level of the ocean;* and from the occurrence of old sea beaches several hundred feet above the present level of the sea (See p. 43).

When the sea stood at its highest level, viz., when the land was lowest, the highest sea-beaches were formed. The 2d epoch, then, gradually passed into the 3d epoch, of marine beaches.

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* At Montreal there are marine clays 470 feet above the St. Lawrence river. For numerous other facts see Dana's Manual, 3d edition, pp. 552-3.

Now the land began to sink, and the ocean drained off, and the floods caused by the gradual melting of the glaciers were drained off through the rivers. This epoch was the 4th one, that of river-terraces. During this time the waters of the estuaries, or mouths of the present rivers, formed the lower or more recent sea beaches, while at the heads of the rivers the fresh-water terraces so characteristic of the rivers of New England and British America were formed. The land was covered with broad lakes connected by rapid rivers; in other words, the larger rivers were chains of lakes. This was, then, a period of broad rivers and extensive lakes. The proofs of this are to be seen in the present river-terraces which are situated often several miles back of the present streams, and from perhaps a few feet to 240 feet, as at Hanover, N. H., above their present level; and in the flat plains, called "parks" in Colorado, which are old lake-bottoms. At the close of this time the present intervales and swampy tracts began to be formed.

It is an interesting fact that most of the towns and villages of the Northern States are built upon the lower river-terraces and on the old lake-bottoms. Thus the land was prepared for the abode of a civilized people.

Moreover, the Great Lakes are bordered by fresh-water terraces which rise from 300 to 500 feet above the present level of the lakes. This proves that the Great Lakes were vastly larger than at present, and that the prairies of the upper Mississippi Valley are the fine sediments which formed the bottom of these lakes.

The plants and animals of the Glacial period were few in species compared with the vegetation and animal life of the close of the Tertiary; but the sea was rich in Arctic shells and other forms now characteristic of the Arctic seas. These animals afforded food for the seal (Fig. 1) and walrus (Fig. 2), whose bones occur in the brick-yard clays of New England. The bones of the white whale (Fig. 3) occur in Vermont on the shores of Lake Champlain, which was formerly an arm of the sea. The hairy mammoth (Fig. 4) and mastodon (Fig. 5) then lived in herds not far from the edge of the glaciers; and without doubt the arctic fox (Fig. 6) and hare (Fig. 7) tenanted the hillsides left bare of ice. Remnants of the Arctic vegetation of the Glacial Period occur in abundance on the Alpine summits of the White Mountains, of Mount Ktaadn in Maine, and along the coast of Maine and of Labrador.

The bones of the mammoth, the mastodon, arctic musk sheep (Fig.), the *Castoroides*, the great bison (*Bos latifrons*), deer, elk and reindeer are found in the northern States in swamps overlying the river-terraces. This shows that these creatures became extinct at the opening of the present epoch, when the country had assumed its present configuration, and when the vegetation and climate were nearly if not quite the same as at present. Having escaped extinction during the great changes from the Tertiary to the Glacial Period, the mastodon and mammoth passed away, after the present climatic and faunal features of our country had been assumed.

When did man appear? Space will only allow us to briefly give the conclusions now generally accepted by those best qualified to judge. In Europe remains of man, a race as well developed as the savage tribes of America, and perhaps more like the Tartars of Northern Asia and the North American Indians (namely, peoples of Mongolian stock) than any other great race, are found associated with the bones of extinct animals such as the mammoth, cave lion, cave bear and rhinoceros, with many others which inhabited Europe, at a time when the rivers stood at a much higher level (perhaps 100-200 feet) than at present. The earliest prehistoric races, then, in Europe were post-glacial, and of the Terrace Epoch. In this country human stone implements occur in river gravels in New Jersey of apparently about the same age as those of the River Somme in France.

In California it is claimed that a human skull and fragments of human bones, with mortars and other stone implements of stone, occur associated with the bones of several extinct animals, such as the mastodon, elephant, tapir, with which were associated the bones of the bison and the modern horse.

The formation in which the remains of man in California occur is probably of the age of the Equus beds of Oregon and of the cave deposits of Pennsylvania and Virginia. The question arises whether this formation is late Tertiary, or early Quaternary, or whether it is not possible that the Equus epoch persisted in the Southern States and on the Pacific coast where there were no glaciers and the climate was mild, and thus overlapped the Sea-beach and Terrace epochs of the Northern States. Whether man was pre-glacial on the Pacific coast is not settled, and whether the Pacific coast man of the Equus beds was of higher antiquity than the Palæolithic man of Europe and Asia may be questioned. The best authorities seem to agree, however, that the early American man emigrated from Asia by way of the Kuril Islands and the Aleutian Islands; that probably from the Valley of the Columbia river he spread out over North and South America. Hence the American man is probably of more modern origin than the primitive races of Asia and Europe. How long, then, has man been upon the earth? Accepting provisionally Croll's estimate of the length of the Glacial Period, that it began 250,000 years ago, and that the ice melted away about 80,000 years before the present era, it is a moderate statement to make, that the earliest race of man of which any traces are left to us, made his appearance upon our earth, probably in Central Asia, from 50,000 to 100,000 years ago. That man in this country was contemporaneous with the mastodon and mammoth is very probable. Professor Leidy has claimed, on partial evidence (a complete skull not having yet been found), the existence of a truly American species of elephant (*Elephas americanus*), representing in the new world the European and Arctic hairy mammoth. This species replaced, in the warmer parts of our country, the Siberian elephant. Its remains, like those of the mastodon, are found at the bottom of swamps and in the upper strata of river sands. The remains of the mastodon, found lately in Indiana, occurred in a peat-swamp four feet beneath the surface, over a bed of marl containing fresh-water shells like those now inhabiting the State. This willow swamp had been flowed by the beaver, and its dam and evidences of lakes were still remaining. Indeed, there are accounts, which, however, need confirmation, of mastodons' bones being found in the Western States, associated with arrow-heads and other Indian relics, as if the creature had been mired in some "lick," and killed by Indians. The mastodon seems to have been more abundant in the Middle States than the mammoth. The habits and geographical range of the two animals, however, seem to have been very much the same. A species of mastodon inhabited the Pampas of Brazil, the bones having been found in the bone-caves of Brazil, and the *Mastodon Humboldtii* lived among the Andes. The northern *Mastodon giganteus* fed on the spruce and fir trees. The food of the tropical existing species is well known to consist of the leaves and succulent branches of trees.

It is not improbable, then, that the earliest American Indian races may have assisted in the extinction of the mastodon and mammoth.* The figures of elephants forming Indian pipes found in mounds in Iowa may possibly indicate that the engravers were not unfamiliar with those animals.*

"It must seem strange to many of our readers to have had introduced, as a characteristic feature in our landscapes of pre-historic times, herds of wild elephants much exceeding in size the tamed imported specimens that march servilely through our towns and villages. How would the children of to-day grin and wonder with patriotic glee, should a squad of veritable *American* elephants stalk through the gaping throng! Such fortune fell only to the lot of the pre-historic urchin. What glorious times were those when the children of the mound-builders, perhaps, trooped on gala days of antediluvian rejoicing, to see trained lions and learned horses exhibit in the circus of those days (if the Pre-adamites were circus-goers), saw the Megatherium fed, the hunger of the Megalonyx and Mylodon appeased with small forests of saplings; and—crowning delight of all—rode on the backs of docile mammoths and more than elephantine mastodons!"*

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* See Mr. Barber's article on Indian pipes, in the *American Naturalist*, April, 1882.

We have endeavored to present in plain language a summary of the leading events in the history of our continent, and of the assemblages of life which have successively peopled its surface and the depths of the sea which washed its shores.†

We have seen that at first only marine types of life prevailed. As the continent grew and the land became fitted for terrestrial vegetation, plants of a comparatively low and generalized structure appeared. At first only invertebrates inhabited sea and land. Then fishes appeared, but none were like our bony fishes, of which there are now nearly 10,000 species, for they belonged to old-fashioned types, of which now there are very few survivors.

The next higher type, the amphibians, then appeared, but they were composite, larval forms, the tailless species, such as frogs and toads, not appearing until the Tertiary. Reptiles also of composite, generalized shapes, preceded the more specialized, modern forms. Birds and mammals, belonging to the lowest subdivisions of their respective classes, appeared in the Jurassic, the modern forms, especially of mammals, not appearing until the continent assumed its present size and diversified contour, where different regions have each their own climate and their own assemblage of life-forms. As a great poet has said—

"All nature widens upward, evermore
The simpler essence lower lies:
More complex is more perfect—owning more
Discourse, more widely wise."

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* The Hairy Mammoth.—*American Naturalist, Vol.* 2, *p.* 23, 1868.

† Allowance must be made by the critic for the brief space allotted us for this purpose, and for errors and shortcomings in the diagrams, as many, if not all of the restorations are confessedly mere attempts to show, in a conjectural manner, how the extinct animals may have appeared. It is hoped that these pages may lead the reader to consult the works of Dana, Lyell, LeConte and others.

Such, then, is the story of creation. And when we contemplate the creative or evolutional force which is immanent in nature, who can logically deny that here we are dealing with the evidences of the existence of an all-pervading and all-wise Intelligence outside of the material world, the Origin and Creator of all things?

EXPLANATION OF DIAGRAM X.

Fig. 1. Mammoth. After Brandt.
2. Reindeer. From Caton.
3. Arctic Fox. From Brehm.
4. Arctic Hare. After Elliott.
5. Walrus. After Elliott.
6. Hair seal. After Elliott.
7. Great Auk. After Audubon.
8. White Whale. After Nordenskiöld.

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